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# END RESULTS IN THE COMBINED (COMMANDO) OPERATION FOR MOUTH CANCER

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THE COMBINED "COMMANDO" TYPE of operation for mouth cancer has come into increasing vogue during the past 10 to 15 years and has won wider acceptance, at least partly, because in the proper hands the mortality rate has been reduced to acceptable limits. It involves neck dissection combined with intraoral extension (usually jaw resection) designed to remove the primary tumor and regional lymphatics at one stage. This type of surgical procedure has been tried before—notably by Crile, in the United States about 1900—but has never received any widespread support because of the high morbidity and mortality. The reasons for the modern well trained surgeon's improvement on these efforts are clear to all familiar with the medical advances of the last 2 decades. The technique has been adequately described by many authors. This article will attempt to answer the question as to what has been accomplished in terms of saving patients from death by cancer by the use of this operation.

Cancer therapists, be they radiologists or surgeons, realize that the application of their individual talents is based on the concept of removing the end result of a disease process, the precise nature of which is only dimly understood. Presumably, whatever metabolic aberrations are at work to produce the cancer in the first place remain unchanged by any extirpative procedure and are still at work following a surgical or radiologic convalescence. The limitations of surgical and x-ray treatment are becoming recognized and have prompted gloomy statements and queries as to whether, despite intensive efforts, any progress at all has been made. The answer appears to be that in some anatomic sites little seems to have been accomplished but that this is not true in other types of cancer. In any event, it is wise to pause from time to time and to evaluate our efforts critically and determine the soundness of method and modify it accordingly.

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## TYPES OF CASES

With the exception of lip cancer which is notably less lethal, cancer in other parts of the oral cavity has many points of similarity regardless of whether it originates in the floor of the mouth, gum, tongue, tonsillar pillar, or buccal mucosa. It occurs predominately in males, is squamous or epider-

TABLE I.—ANATOMIC LOCATION IN 58 COMBINED NECK AND JAW RESECTIONS

| | *No.* |
|---|---|
| Gum | 22 |
| Floor of mouth | 9 |
| Tonsil | 7 |
| Lip | 7 |
| Tongue | 6 |
| Buccal mucosa | 5 |
| Pharyngeal wall | 1 |
| Skin of face | 1 |
| Total | 58 |

moid in character in more than 90 per cent of all cases, has a strong predilection for cervical lymph node metastases, and, even in treatment failures, distant metastases occur in only about one-quarter of all cases —death in most instances occurring through failure of control of disease in the oral cavity and neck. Clearly, not every case of oral cancer requires the extensive sacrifice of tissues of the combined operation. Some patients are fortunate enough to obtain a diagnosis when the lesions are small enough to be eradicated by much more limited surgery or by irradiation.

The "commando" operation is adaptable to the removal of primary tumors occurring at several different sites in the oral cavity. Any such series will therefore include a variety of tumors originating in these different locations. This series includes primary tumors which originated in the tongue, gum, tonsillar pillar, floor of mouth as well as some lip cancers in which the primary lesion was previously controlled but metastases to the submaxillary area invaded adjacent bone (Table I). By and large, they were all advanced tumors. Measurements of the excised specimens show the average size of the primary lesion to be 10 square centimeters. Many invaded adjacent periosteum or true bony cortex (Fig. 1). All were squamous or epidermoid cancers.

TABLE II.—THREE YEAR END RESULTS IN "COMMANDO" OPERATIONS FOR MOUTH CANCER (1948 to 1955)

| | | *No. of cases* |
|---|---|---|
| Total No. of cases | | 58 |
| Indeterminate (dead of other causes, no evidence of disease) | | 2 |
| Determinate | | 56 |
| Treatment failures | | |
| Died of recurrent cancer | 24 | |
| Operative mortality | 4 | |
| Living with recurrence | 2 | |
| Total | | 30 |
| Treatment successes* | | 26 |

*No evidence of disease 3 yrs. postoperatively.
3 yr. "cures"—46.3 per cent.

In only 2 instances during this period was a patient refused operation on the grounds that the tumor was too extensive. This figure is important to those who might suspect that the cases were so selected as to include only the more favorable lesions whereas the advanced cases were not accepted for fear of compromising the results. Both patients who were refused operation subsequently died of cancer despite efforts at control with x-rays. From these facts, it may be seen that this series consisted of cases in which treatment by either x-ray or more limited surgical removal has been shown repeatedly to be of little value. Any salvage, therefore, must be considered as a real achievement.

## END RESULTS

During the years 1948 to 1955, a total of 58 operations were carried out. Since analysis of the end results is directed toward answering the question of what is the curability of cancer of the oral cavity when it is so advanced that more limited therapy has been repeatedly proved to be of little value, in this sense, this report is based on a selected group of patients, i. e., those whose lesions were sufficiently advanced as to require the "commando" operation.

The entire group has been evaluated for the results obtained at the end of 3 years following definitive treatment. Although it is admitted that recurrent disease may rarely develop after a 3 year period, this interval is a fair test of effectiveness for this particular variant of cancer. In the group of 30 treatment failures, 4 patients died as a direct result of the operation. Of the remaining 26 treatment failures, in 19 patients (73 per cent) recurrent cancer developed within 1 year following surgery, in 5 patients (19 per cent) the cancer recurred in the second year following surgery, and in only 2 patients (8 per cent) recurrence took place

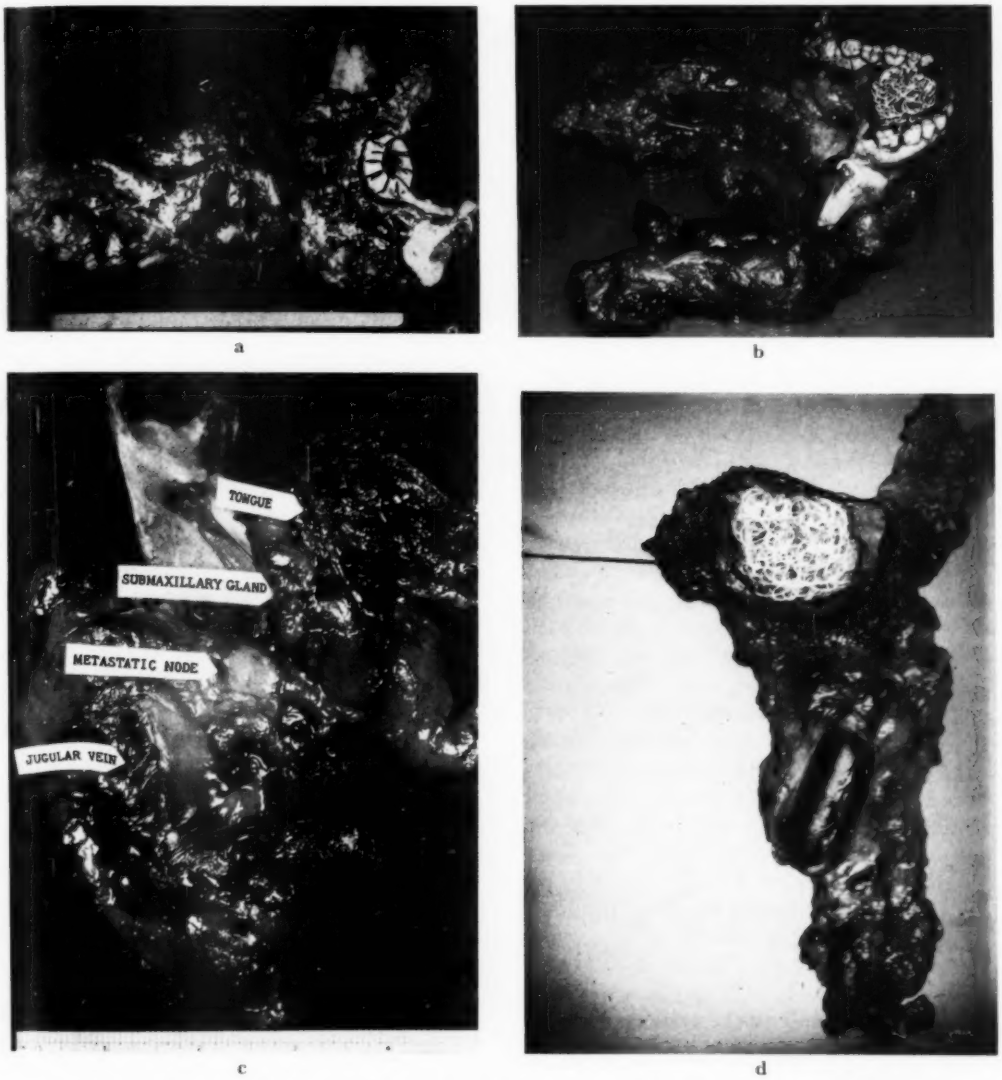


FIG. 1. Examples of representative lesions suitable for treatment by the commando operation. a, Cancer starting in the gum and invading the underlying bony cortex. b, Cancer of anterior floor of mouth invading the symphysis menti with bilateral cervical metastases. c, Advanced cancer of the tongue spilling over onto adjacent ramus of mandible. d, Exophylactic lesion primary in gum invading underlying bone.

during the third postoperative year. In no patient who remained well for 3 years following treatment has recurrence yet developed in this series. Therefore, although in other forms of cancer (breast, melanoma) a 3 year waiting period may be subject to serious limitations, in the type of cancer herein discussed, it does seem to have real significance. The over-all salvage rate in this group of cases was 46.6 per cent (Table II).

MORBIDITY AND MORTALITY

In 58 consecutive cases from 1948 to 1955, there were 4 postoperative deaths (6.9 per cent) most of which occurred during the early years of the series. There has been no postoperative death in the last 22 consecutive cases, and the operative mortality of the entire series to date has been reduced to between 4 and 5 per cent. The 4 postoperative deaths were due to: uncontrolled diabetes in 1 case, postoperative respiratory obstruction in 2, postoperative pneumonia in 1. Routine tracheostomy is now an integral part of the operation. Failure to do this accounted for 2 of the early postoperative deaths attributed to postoperative respiratory obstruction.

Fistulas developed in 24 per cent and healed via secondary intention in every case, no instance requiring secondary closure. Some difficulty in swallowing has been encountered routinely during the first few weeks postoperatively, but all patients recovered the ability to eat via normal channels. The more posterior the oral defect, the more marked was this difficulty.

Restoration has not been successful in the large mandibular defects. Dental prostheses, pins, and bone grafts were used in a small group of patients, but the results were so unsatisfactory that they were soon abandoned. If the defect is small (1 to 2 inches in length) and if a reasonably long proximal segment is left, the defect may be bridged at a later date with a graft.

Unless the symphysis menti is sacrificed, a good cosmetic result can be achieved in these cases. If the symphysis is sacrificed as it must sometimes be for lesions of the anterior floor of mouth, subsequent reconstruction is difficult and usually unsatisfactory. This is at least partly due to the fact that in order to circumvent the tumor adequately, a considerable amount of soft tissue as well as bone must be sacrificed.

Most of the patients have adjusted well to partial loss of the mandible. If they have teeth, they are still able to chew to some degree following the operation. If they are edentulous, it has not been possible to compensate for this deficiency satisfactorily despite the ingenuity of dental colleagues; and such patients must adjust to a soft, mechanically preground diet. In any event, nutrition has not been a problem and most patients have been quite willing to accept this price for getting rid of the tumor.

DISCUSSION

This is a period in which surgery has advanced to the point where patients undergo the most extensive technical procedures with safety. It is not surprising then that disappointment should result from the fact that so many cancer patients die from recurrent disease despite our "surgical triumphs." Without experiencing frustration, who could trace the laborious efforts in the development of gastric resection from the days of Theodor Billroth, when the very possibility of removing the stomach was considered by many to be incompatible with life, to the present day when this operation is widely performed with a mortality of about 5 per cent (for gastric cancer) and reasonable morbidity, only to find that barely 8 to 10 out of 100 patients with gastric cancer remain well over 5 years?

One sees this frustration expressed in phrases such as "biologic predeterminism," meaning that regardless of what efforts at cure are made a large number of patients are doomed to die. This is really only a fancier statement of a fact that has been recognized by many for some years and is equally well expressed by the homely pronunciation: "There are some good tumors and some bad ones." As Stewart has stated, "The reason —the true fundamental reason why one cancer is cured and another that looks much like it is not, is to me entirely obscure. Therefore, I must acknowledge concurrence with those who say that the cure of cancer depends on the biologic character—which however is not very meaningful because it is merely another way of saying that a cancer is cured because there is something about it that is curable."

It seems worth while to point out that the inventors of "biologic predeterminism" have never intended that this concept should be used as an excuse for therapeutic nihilism. More important, it certainly cannot be used to support sloppy or inadequately performed surgery on the grounds that regardless of how well or poorly the job is done, the ultimate result is predestined and cannot be improved by a properly performed surgical procedure.

The practical application of such a doctrine is essentially nil unless someone tells us how to pick out the "good" cancers, those in which the biologic predeterminism is favorable, from the "bad" ones, those in which the biologic predeterminism is unfavorable. To the best of my knowledge, no such criteria are available. All of us have been surprised by the favorable subsequent course of tumors that have been adjudged "advanced" on the basis of size, histologic grading, and age of patient, and have been equally fooled by the adverse course of "favorable" lesions. Are we justified in withholding attempts at cure in the face of these facts? This viewpoint is particularly hard to accept if no alternative course of action is offered. Presumably, other courses of action would consist of doing nothing or doing a "little bit of surgery" or a "little bit of radiation." Such a decision does not take into consideration the natural desire of the patient for someone at least to try to help him, nor is due recognition made of the palliation received even though the patient subsequently succumbs.

Be that as it may, these results in mouth cancer demonstrate that, at least in this instance, a significant number of cases are favorably "biologically predetermined" and are worth the efforts directed at cure. Albert Einstein is credited with stating "God does not cast dice." That is, nature is governed by law, not by chance. Who, for example, could have foreseen any connection between a man falling out of a window and a ship being able to sail around a spherical world without falling off into space until Isaac Newton invented his laws of gravity? The advances in human knowledge have repeatedly demonstrated the assemblage of empiric data that seemingly have no interconnection or common ground until some mind, in a flash of genius, ties them altogether with a natural law or principle. We await the discovery of such a breakthrough in the problem of cancer. Meanwhile, let us recognize and be encouraged by our successes with the tools now at hand as well as stimulated by our failures to find better ones. Results such as these do not support the concept that cancer is a disease whose course cannot be favorably influenced by our efforts when it occurs in these anatomic areas.

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# A VASCULAR STUDY OF THE SMALL INTESTINE

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THE VIABILITY of an organ is directly dependent upon the blood supply. This was amply demonstrated by Benjamin (1) in the study of the vascular anatomy of the stomach.

Because of the more drastic surgical attack on the aged in the surgery of the small intestine, either because of disease due to arteriosclerosis or because of thrombosis associated with heart disease, we believed it was imperative to investigate the blood supply of the small intestine, as we had previously done with the stomach. A study of the small intestine is not a new field of investigation as Noer (11) stated: "Andreas Vesalius, in 1540, presented an interesting, and for that day, surprisingly accurate illustration of the small intestine and its blood vessels. . . ." Estien, a contemporary of Vesalius, also made a like study with illustrations of the small intestine and its blood vessels.

Modern advances in instrumentation and methods, as well as anesthesia and surgical approach, have made it possible to do massive resections of the small intestine, especially in the aged, who, because of their age and physical status, are poor risk patients. Because of the nutritional state of the aged individual and because of the extreme importance of maintaining normal function, it is important to conserve as much of the intestine during the resection as is feasible, and this depends upon a clear and concise knowledge of the blood vessels of this organ.

Previous observation of the vascular architecture as well as the neurophysiologic mechanism of the stomach and duodenum demonstrated a fairly simple and practical anatomic distribution of the blood vessels to the muscular layer as well as the mucous membrane. We believe that the blood vessels perforate the serosa and muscular layers much as the urethra enters the bladder (Figs. 6 and 7). This is of physiologic importance, as marked intraluminal pressure of an organ tends to impede flow as well as to prevent regurgitation of blood within the vascular system.

We also saw that the entire gastrointestinal tract basically consists of a sleeve within a sleeve, thereby allowing the inner sleeve, namely the mucous membrane to slide back and forth within the outer sleeve, namely the muscular layer. Between these tubes is a loose areolar area within which runs the main blood vessel and from this main blood vessel branches go to the muscularis as well as the mucosal areas (Figs. 6, 7, and 8). With this in mind, we elected to study the vascularity of the small intestine.

The intestinal tract beginning with the duodenojejunal flexure at the ligament of Treitz to and including the ileocecal junction is supplied principally by the superior mesenteric artery, the second of the three ventral branches of the abdominal aorta (Fig. 1). The venous drainage is carried on by one of the major tributaries to the portal system, the superior mesenteric vein. To make up the portal system, both the superior mesenteric vein as well as the splenic vein are the prime contributors.

The three standard textbooks of anatomy are in agreement that the jejunum and ileum are supplied by the superior mesenteric artery, and that a series of 10 to 16 intestinal arteries rise from this major source of supply. They bifurcate distally in such a way as to form intestinal arcades which increase in number from the jejunum to the ileum. The vasa recta emanate from the intestinal arcades and directly supply the small intestine. At this point there is

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divergence of opinion in the current literature. The vascular architecture of the intestine as presented in Morris' *Anatomy* states: "These terminal jejunal and ileal arteries bifurcate as they approach the mesenteric attachment, and their branches pass to either side of the gut, sending penetrating twigs into the gut wall. Some of their smaller branches continue superficially and effect anastomoses at the antimesenteric border with the branches from the opposite side, thus forming a series of small vascular rings about the small intestine. In addition to these circular anastomoses there are side-to-side anastomoses between smaller branches of adjacent intestinal vessels providing a mechanism for collateral blood supply along the length of the intestine." A somewhat different account is found in Gray's *Anatomy*, namely: "From the terminal arches numerous small straight vessels arise which encircle the intestine, upon which they are distributed, ramifying between its coats. From the intestinal arteries small branches are given off to the lymph glands and other structures between the layers of the mesentery." On the other hand, Cunningham states that: "The branches from the terminal arcades pass to the wall of the gut, generally to one or the other side, but occasionally a terminal branch divides and passes to both sides." Cokkinis stated that the terminal branches from any one terminal arcade neither anastomose with one another nor with the branches of adjacent terminal arcades. Ross (13, 14) and Doran showed, by means of corrosion preparations, that they do in fact anastomose in the wall of the gut; and, therefore, these terminals no longer may be regarded as end-arteries. With such a divergence of opinion we began our investigation of the arterial blood supply of the small intestine.

A comparative study of the stomach (1, 2, 3), with those of the small intestine, dramatically points out nature's tendency to duplicate her successful results in similar organs whenever possible. This statement is made in the light of observations made on the vascular configuration of the mucous membrane and muscular layers of both the stomach and small intestine.

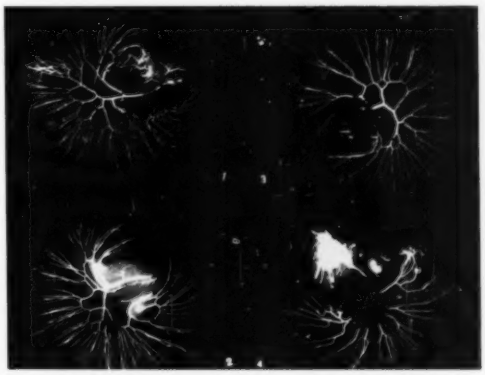

FIG. 1. Photograph of a human specimen of small intestine showing the accepted anatomic textbook picture of the mesenteric blood vessels. The intestinal branches of the superior mesenteric artery divide to form arcades. Vasa recta originate from the arcades. (*1*) Ileal region showing primary, secondary, and even tertiary arcades. The vasa recta are correspondingly short. (*2*) Portion of the organ showing primary and secondary arcades. (*3*) Portion of the organ showing primary arcades as well as occasional secondary arcades. (*4*) Portion of the organ in the jejunal region. An occasional primary arcade is seen. The vasa recta are the longest in this part of the small intestine.

## MATERIALS AND METHODS

At the outset of this project, it was decided that this study of blood vessels would be dependent upon a specific sized contrast injection medium in order to visualize the largest as well as the smallest blood vessels. Numerous materials were used, but as in previous work it was decided that bismuth oxychloride was ideal for this work, especially in view of the fact that its particulate size was such as to be just large enough to stop at the capillary bed on the arterial side. Diodrast was another contrast medium used. Because of its low toxicity and high contrastability, this material was used in the living subject. The specimens used were both human and canine. The canine specimens of small intestine were divided into two groups, normal and experimental, the

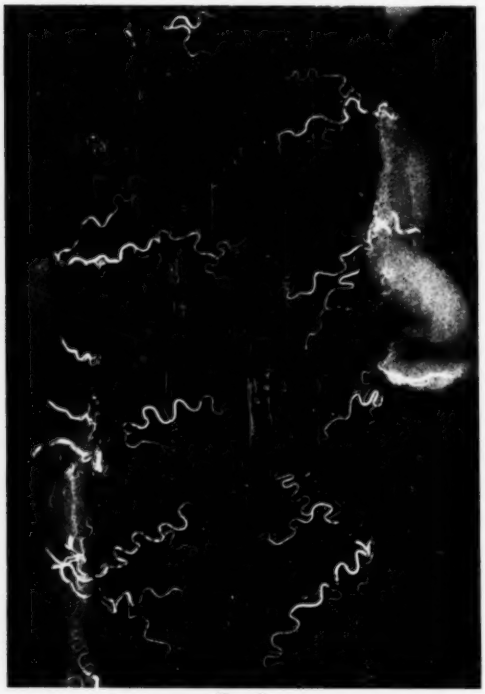

FIG. 2.

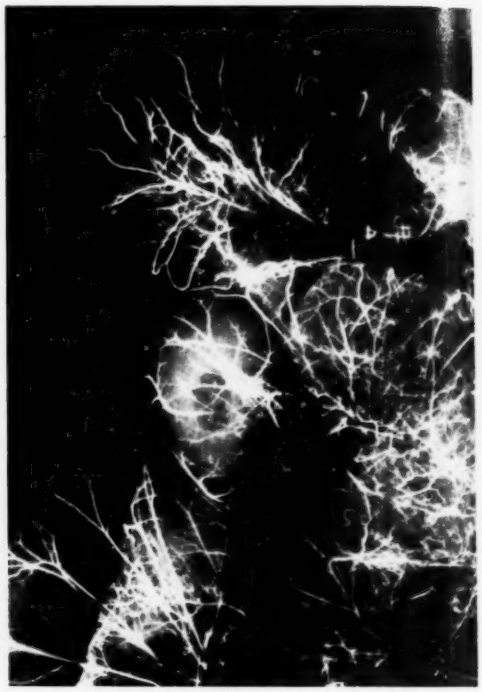

FIG. 3.

FIG. 2. Photograph of a human specimen of intestine opened along the mesenteric border. (Note: mesentery can be seen along both edges of the specimen.) Here is a relatively good representation of anastomoses taking place in two directions. Parallel to the long axis of the organ are communications between adjacent vasa recta. Perpendicular to the long axis of the organ are communications between the vasa recta of the opposite sides.

FIG. 3. Photograph of an experimental canine specimen of intestine demonstrating a deviation from the classical surgical procedure, in which a rectangular segment of the organ is resected. The two ends of the intestine are then approximated end-to-end. Note the extreme vascularity of the area of approximation.

latter being used for specific surgical procedures. Two methods of injection were used here, the simple syringe method, in which the medium was injected by means of a 50 cubic centimeter syringe into the blood vessel using a cannula, or by air pressure through a reservoir within which the medium was suspended. The human intestines were obtained at postmortem examinations. The canine specimens were obtained following surgical procedures. The injections were done while the animal was anesthetized, using the heart as the pumping agent.

To study the minute blood vessels in the mucous membrane of the small intestine, we again had recourse to the use of the grenz ray (Figs. 6, 7, and 8), a method which had proved highly satisfactory on previous occasions. Grenz rays are very soft roentgen rays, having a wave length of about 2 angstrom units. These rays lie between the roentgen rays and the ultraviolet rays and, as a result, have a very shallow penetrating power. All specimens were studied by means of conventional x-rays and grenz rays. In all cases, x-ray films were taken of the gross specimens, but for the study of the finer ramifications of the intramural vessels, grenz rays were utilized.

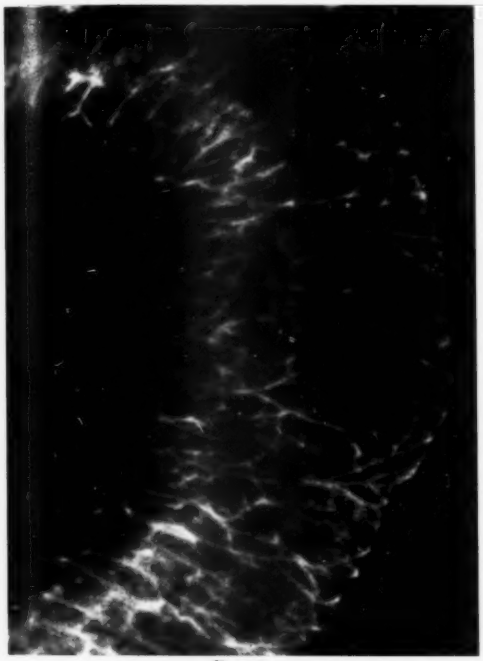

FIG. 4.

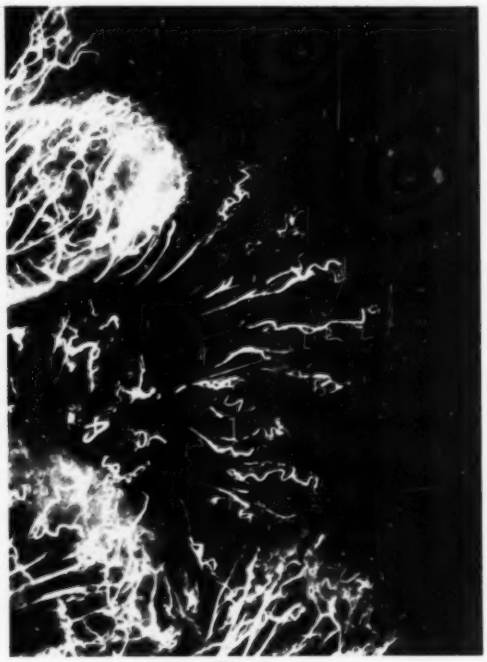

FIG. 5.

FIG. 4. This is a photograph of a canine specimen of intestine showing the complexity of the vascularization of the small intestine. Note the anastomoses between adjacent vasa recta.

FIG. 5. Photograph of a human specimen of intestine showing the following types of anastomoses: on the lateral aspect of the wall are communications between adjacent vasa recta and on the free border of the organ are communications between adjacent vasa recta as well as communications between the vasa recta of the opposite side.

The other method of study, using diodrast as a contrast medium, was attempted in 3 cases using the dog as the experimental animal. This rapidly dissipating medium was injected into the superior mesenteric artery by means of a cannula thereby demonstrating the blood vessels of the small intestine of the living anesthetized animal. At the same time roentgenograms were taken. In each of the cases 12 roentgenograms were taken at half-second intervals with an exposure of 1/10 second for each at 100 milliamperes 50 kilovolts. The tube distance was 48 inches. The table-top technique was used without grids.

Intestinal surgical procedures were performed with the expectation of forming new blood vessels in the adhesive contact bands of the surgical intestinal wounds. Having observed that the surgical texts have, from time immemorial, advised that all resections of small intestine be triangular with the apex directed into the mesentery so as to preserve as great a blood supply as possible for future healing, it was decided to investigate the veracity of this statement. Resections of the small intestine were done as the texts suggested and because of previous observations of the adequacy of the intramural blood vessels, transverse resections were done. These specimens were injected in vivo with diodrast.

Both the end-to-end and the end-to-side anastomotic procedures were instituted. The procedure used was as follows: first, the dogs were anesthetized by intravenous injections of nembutal (25 mgm./kgm. of body weight). A midline incision was made

FIG. 6.

FIG. 7.

FIG. 6. Photograph of a grenz ray study showing the signet ring effect of the blood vessels in a normal canine specimen of intestine (⅛ inch thickness). Here is demonstrated the vascular pattern of the submucosal and mucosal plexi of vessels with their communications. In several areas are seen branches which double back to the serosa.

FIG. 7. Photograph of a grenz ray preparation of a normal canine specimen of intestine sectioned at 150 microns showing the signet ring effect of the intramural vessels. Here, also, is demonstrated the vasa recta piercing the serosa and longitudinal and circular muscular layers to enter the "loose areolar highway" or submucosa. From this region branches are given off to the mucosa and to the serosa.

through the skin, fascia, and peritoneum. The small intestine was mobilized, and the jejunum and ileum were identified. Depending on the purpose of the experiment, the next step was modified accordingly. If the small intestine was to be removed for injection only, then the bleeders were tied off as they occurred. The superior mesenteric artery was the last vessel to be dissected. The small intestine was then removed for injection. If, however, the procedure was to experiment with the types of resection, the jejunum and ileum were identified and either the end-to-side or the end-to-end type of anastomosis was performed. The wound was then surgically closed and the animal allowed to recover for future vascular injection studies. This was done in order to demonstrate the newly formed blood vessels in the surgical intestinal scar.

In 2 of the 3 cases an end-to-end anastomosis was made at 2 sites along the organ. At one site, the classical procedure of making an angular incision was accomplished. At the other site, an experimental procedure was attempted in which a segment was removed at right angles to the long axis of the organ. The two cut ends were then approximated. In the third case, an end-to-side anastomosis was performed.

The postoperative procedure was as follows: each of the animals was given combiotic therapy, 1,000,000 units, for 5 days. Until the animal could tolerate a regular diet, it was given milk and bouillon twice daily. Fourteen days was the period elected as the survival time. At this time the abdomen was opened and the site of surgery was examined grossly. Bismuth oxychloride was then injected intra-arterially and roentgenograms were taken for vascular study.

OBSERVATIONS

Both human and canine intestinal specimens, when injected, conformed, in general, to the vascular arrangement described in the conventional anatomic textbooks. This vascular pattern was clearly observed in Figure 1.

Bismuth oxychloride, the contrast medium elected, in the main, made this task relatively easy as only the arteries down to capillary level were packed with the contrast medium because of its particle size. Other features of this material warranted its continued use, those features being that its opacity lends itself to x-ray studies, that it remains in suspension with relative ease, and that its viscosity allows for complete packing of the vessels down to the capillary level.

Figures 1 through 5 exhibit the gross arterial pattern of the small intestine as they are found in the dog and in man. The mesenteric arcades give origin to the vasa recta which then can be seen to bifurcate in the dog (Figs. 3 and 4) as well as in man (Figs. 1 and 5). In the region of the vasa recta a difference exists between the pattern seen in the dog and that seen in man. Although all the vasa recta in the dog bifurcate, there are areas of communication between adjacent vasa recta just prior to the penetration of the intestinal wall. These same communications do not exist in man.

DISCUSSION

The grenz ray preparations, in the role of modern instrumentation and methods, have provided a unique means of investigating the vascularization of the small intestine. In Figure 8 one is impressed with the multitude of anastomoses between the intramural vessels as well as the magnitude of the main arteries in the "loose areolar pathway." There are numerous anastomoses in a direction parallel with the long axis of the organ. First, on the lateral aspect, there are communications between adjacent intramural vessels (Figs. 4 and 5). Secondly, on the free border there are also communications with adjacent intramural vessels as well as communications between intramural vessels of the opposite side (Figs. 2, 3, and 5). In Figure 8, there are exhibited branches arising from the main arteries of the submucosa a vast number of branches which course to the outer sheath (not visible) and to the inner sheath (right side of the figure) in a direction which is perpendicular to the long axis of the organ. Because of the number and magnitude of the main arteries of the small intestine, it is readily understandable that the intramural blood supply is more than adequate. This tool, the grenz ray, has provided a means of comparing the vascular pattern of the small intestine with that of the stomach with respect to the

FIG. 8. Photograph of a grenz ray study of a normal canine specimen of intestine sectioned at 150 microns and magnified by 63. Shown here are anastomoses between the submucosal (left) and the mucosal (right) plexus of arteries. Present in this figure is the main artery of the submucosa with a number of branches directed toward the mucosa. The impressive number of blood vessels substantiates the fact that the intestinal mucosa acts as an absorbing membrane in the process of digestion.

vascular configuration of the mucosa and muscular layers. As nature has done so many times with respect to other parts of the body, so too, has it been accomplished with respect to the gastrointestinal tract. Nature has reduplicated herself in the small intestine by repeating the vascular pattern laid down in the stomach.

SUMMARY

Observations of the major blood vessels of the small intestine are in agreement with the literature. Mayo states: "Although there are many intramesenteric anastomoses between arteries that supply the small intestine, the vessels are small and no true 'marginal artery' exists, as is true of the blood vessels that supply the colon." From those specimens injected, this does not completely hold true. Few, if any, intramesenteric anastomoses were seen in the human small intestine. As Noer (10, 12) states in his comparative study of the small intestine, the intramesenteric anastomoses which are seen between adjacent vasa recta on the mesenteric border constitute an additional route for collateral circulation in the dog which man does not have. It is true, however, that these communications do not constitute a true "marginal artery" in the dog. These intramesenteric anastomoses, in the dog, are most demonstrable when diodrast was used as the contrast medium.

Examination of the vasa recta differs with the explanation given in Morris' *Anatomy* in that the vasa recta, once they have pierced the serosa, do not "continue superficially to effect anastomoses on the antimesenteric border. . . ." From observations made on the injected small intestine these anastomoses take place in the region of the submucosa. There is contradiction in the statement presented in Cunningham's *Anatomy* that "only an occasional branch from the terminal arcades bifurcates to pass to either side of the gut. . . ." It can be seen upon examination of any of the gross figures that all of the vasa recta bifurcate to pass along both sides of the small intestine. On the other hand, Gray's *Anatomy* offers the best explanation of the finer ramifications, but no mention is made as to the intramural anastomoses and where they occur.

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# AN EXPERIMENTAL STUDY OF ARTERIAL REPLACEMENT IN THE PRESENCE OF BACTERIAL INFECTION

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IN RECENT YEARS arterial replacement with freeze-dried homografts and synthetic fabric prostheses has become an established and commonplace operative procedure. In general, both homografts and synthetic prostheses have proved satisfactory as arterial substitutes. With any new operative procedure, as experience accumulates unforeseen problems are encountered. Early in our experience with freeze-dried homografts an unexpected complication occurred. During the resection of an arteriosclerotic aneurysm of the abdominal aorta an unsuspected retroperitoneal abscess was found overlying the aneurysm. This abscess had formed in the hematoma of a self-limited rupture of the aneurysm. Following resection of the aneurysm and evacuation of the abscess, a freeze-dried homograft was interpolated to restore arterial continuity. Six days later, after a febrile postoperative course, the patient suddenly lapsed into shock. At reexploration the homograft was found to have partially disintegrated with resultant massive hemorrhage. On 2 other occasions, in a series of 150 freeze-dried homograft implantations, the graft was disrupted in the presence of infection. Similar problems have been reported by other authors.

This experience raised the question of the optimal method of management of arterial replacement in infected sites and contaminated wounds. This problem is of special significance for the military surgeon and for any surgeon dealing with extensive trauma. The basic question is whether an arterial homograft or a synthetic fabric prosthesis would function best in the presence of infection.

Freeze-dried homografts and synthetic prostheses are nonviable and potential foreign bodies. It is obvious that the proteolytic enzymes of an infection might lead to dissolution of a homograft. On the other hand, a synthetic prosthesis might serve as a nidus for chronic infection.

This study was undertaken to evaluate the performance of freeze-dried homografts and synthetic fabric prostheses as arterial replacements in infected sites and contaminated wounds.

## METHODS

In adult mongrel dogs weighing 9 to 15 kilograms para-aortic infection was induced by two methods.

*Para-aortic retroperitoneal abscess.* After preliminary studies a method of inciting a standard para-aortic abscess was developed. At laparotomy, under direct vision, 1 cubic centimeter of a saline suspension of canine feces was injected retroperitoneally and adjacent to the lower abdominal aorta. Forty-eight hours later an abscess containing 5 to 10 cubic centimeters of thick pus developed adjacent to the aorta. At this time a second laparotomy was performed. The abscess was opened, cultured, and evacuated. Bacteriologic cultures consistently revealed coliform organisms: Escherichia coli, Proteus vulgaris, and Aerobacter aerogenes. The adjacent aorta was mobilized and a 4 centimeter segment resected and replaced either by homograft or synthetic fabric

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FIG. 1. Freeze-dry homograft 4 years after implantation in abdominal aorta of dog.

prosthesis. Animals were operated upon in pairs in order that comparable conditions might exist for the two arterial substitutes. Anastomoses were performed with No. 5-0 arterial silk, employing the Carrel triangulation technique. Intravenous pentobarbital anesthesia was employed for all operations.

*Simultaneous retroperitoneal contamination and aortic replacement.* In order to simulate a contaminated wound involving a major artery the following technique was employed. Animals were again submitted to laparotomy in pairs under pentobarbital anesthesia. The retroperitoneal space was opened and 5 cubic centimeters of a saline suspension of canine feces were placed adjacent to the aorta. The aorta was mobilized, resected, and replaced by either homograft or synthetic prostheses. This preparation closely approximates the problem encountered in a wound involving the colon and abdominal aorta.

The canine homografts employed in this study were sterilized with ethylene oxide and preserved by freeze-drying. The details of the processing and preserving procedure were described in an earlier publication (1). The synthetic fabric prosthesis selected for this experiment was a tightly woven seamless nylon tubing. For the purposes of the study this fabric was considered to be fairly representative of this class of prosthesis.

FIG. 2. Synthetic prosthesis demonstrating disruption of suture from host aortic side of anastomosis. Thin layer of fibrin lines the prosthesis.

The lower abdominal aortae of the animals used in this study varied from 7 to 9 millimeters in diameter. A variety of homografts and nylon tubing of various sizes were available at each operative procedure so that a proper replacement could be selected. The homografts and synthetic prostheses were sutured under slight tension to avoid redundancy and subsequent kinking. The nylon tubing was cuffed at either end and a small wedge cut from the cuff to avoid wrinkling.

Early in the study it became apparent that regardless of the mode of infection or the type of substitute employed, if antibiotics were not administered all animals died in 4 or 5 days. Death was the result of peritonitis or hemorrhage following breakdown of graft or a suture line. Accordingly, variations in antibiotic therapy were used to delineate differences in the performance of the freeze-dried homograft and the synthetic prosthesis.

Since April 1954, freeze-dried homografts and synthetic prostheses have been placed in 140 dogs. In 120 of these animals retroperitoneal para-aortic infection was induced. The remaining 20 animals were controls without infection.

## RESULTS

*Control group A.* In a group of 20 animals freeze-dried homografts and seamless nylon tubing were used to replace a 4 centimeter segment of the lower abdominal aorta. These animals did not receive antibiotic therapy nor was the retroperitoneal space contaminated. All 20 animals survived—10 in each group. In 1 animal in each group thrombosis of the graft developed. The nylon prosthesis which thrombosed was shown to be patent by aortography 2 weeks after

implantation but with slight narrowing at the proximal suture line. Four weeks later it was completely occluded. The homograft which thrombosed was discovered on routine aortogram 6 weeks after implantation. The remaining 18 control animals have now survived 24 to 48 months with patent grafts (Fig. 1).

*Control group B.* In a group of 10 dogs para-aortic abscess was created by the method cited above. Forty-eight hours later homografts and nylon prostheses were interpolated following aortic resection. These animals did not receive antibiotic therapy. In 4 to 5 days all the animals were dead. The cause of death in each group was hemorrhage in 2 and peritonitis in 3 dogs. The mode of death and average time of survival in both the homograft and nylon prosthesis groups were the same. The cause of the hemorrhage, however, in the two groups was quite different: hemorrhage in the nylon prosthesis animals followed disruption of the sutures from the host aorta, but in the homograft animals the sutures had pulled out of the homograft itself (Fig. 2 and Fig. 3).

*Infection group I.* In a group of 20 animals a para-aortic abscess was created. Homografts and synthetic prostheses were implanted 48 hours later as outlined in the foregoing. At the time of graft implantation these animals received 300,000 units of penicillin and 0.5 gram of streptomycin intramuscularly and this dosage was continued once daily for 6 days. In the homograft group 1 animal survived with a thrombosed graft. The remaining 19 animals died in from 6 to 9 days of hemorrhage or peritonitis: 8 of the homograft group died of hemorrhage, 1 of peritonitis; 3 of the prosthesis group died of hemorrhage, 7 of peritonitis. Hemorrhage in the nylon prosthesis group followed disruption of the sutures from the host aorta. Hemorrhage in the homograft group was due to sutures pulling out of the homograft in 4 animals and followed rupture of the homograft itself in 4 other animals (Fig. 4).

FIG. 3. Homograft demonstrating disruption of suture from graft as cause of exsanguinating hemorrhage.

*Infection group II.* In 30 animals para-aortic abscess was created and the arterial substitutes implanted 48 hours later. Antibiotic therapy consisting of penicillin and streptomycin was administered for 6 days beginning 24 hours prior to graft implantation. Thus antibiotics were started 24 hours after para-aortic contamination and 24 hours before graft implantation. There were several differences in the results in the homograft and synthetic prosthesis groups. Forty-five per cent (7 dogs) of the animals with nylon prostheses survived (1 with a thrombosed graft) whereas only 7 per cent (1 dog with a thrombosed graft) of the animals with homografts survived. Ex-

FIG. 4. a and b, Homografts that have undergone central rupture in the presence of bacterial infection.

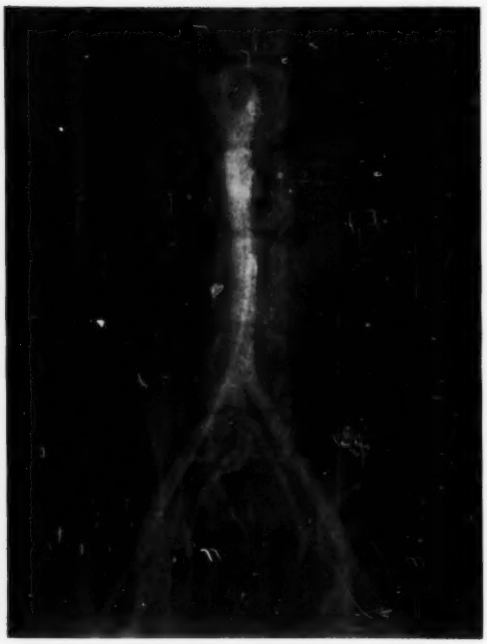

FIG. 5. Retrograde abdominal aortogram in a dog with homograft replacement of lower abdominal aorta 18 months after graft implantation. There is a slight deviation of aorta to the left at site of proximal suture line.

FIG. 6. Retrograde abdominal aortogram in a dog with nylon prosthesis replacement of lower abdominal aorta 12 months after graft implantation. Slight narrowing at proximal suture line can be detected.

sanguinating hemorrhage was the cause of death in 12 (80 per cent) of the animals with homografts but in only 4 (27 per cent) of the animals with nylon prostheses. Hemorrhage in the homografted group was due to disruption of sutures from the homograft in 7 animals and due to rupture of the graft itself in 5 animals. Hemorrhage in the nylon prosthesis group was due to sutures pulling out of the host aorta exclusively. Peritonitis was the cause of death in 3 of the homograft group and in 4 of the prosthesis group. The average time of survival in these animals that died, following graft implantation, was 9 days for the synthetic prosthesis group and 5 days for the homograft group.

*Infection group III.* This group consists of 40 animals in which para-aortic abscess was induced or the para-aortic tissues were contaminated at the time of graft implantation. Freeze-dried homografts and seamless nylon tubing were implanted as outlined for each method.

Penicillin and streptomycin were administered for 6 days beginning 24 hours prior to grafting. In addition, a 1 per cent solution of neomycin was used to irrigate the retroperitoneal, para-aortic tissues following graft implantation.

Once again there were notable differences in the homograft and nylon prosthesis groups. Forty-five per cent (9 dogs) of the animals with nylon prostheses survived (1 with a thrombosed graft) whereas only 25 per cent (5) of the homograft group survived (1 with a thrombosed graft). Exsanguinating hemorrhage was the cause of death in 70 per cent (14) of the animals with homografts and 10 per cent (2) of the animals with nylon prostheses. Hemorrhage was the result of rupture of the homograft in 6 animals and dehiscence of sutures

from the homograft in the remaining 8 animals. Hemorrhage followed disruption of sutures from the host aorta in the 2 animals with nylon prostheses. Overwhelming peritonitis was the major cause of death in the nylon prosthesis group—in 9 animals of the prosthesis group and in 1 of the homograft group. Of the animals which died, the average survival time following graft implantation was 10 days for the synthetic prosthesis group and 6 days for the homograft group.

*Infection group IV.* Two observations made in the earlier studies led to the creation of this phase of the experiment. First, bacterial culture and antibiotic sensitivity studies in the earlier groups consistently revealed bacterial organisms that were sensitive to chloramphenicol. Secondly, it was noted in those animals which died, that death occurred several days after antibiotic therapy was discontinued. Accordingly, in 20 animals grafts were implanted following abscess induction or contamination of the paraaortic tissues. Penicillin and streptomycin therapy was extended from 6 to 14 days. Local neomycin solution was used as in group III. In addition, 0.5 gram of chloramphenicol was administered intramuscularly every 12 hours for 5 days. The results in the two groups were identical: 9 animals in each group survived. Freeze-dried homografts and seamless nylon tubing proved successful in 90 per cent of the animals. There were no deaths due to peritonitis alone and 1 animal in each group bled to death: the sutures had pulled out of the homograft in 1 animal and out of the host aorta in the animal with a nylon prosthesis.

## RESULTS OF FOLLOW-UP STUDIES

*Aortograms.* Retrograde aortograms via the femoral artery were performed 6 weeks after grafting and at 3 to 6 month intervals thereafter. Seven instances of thrombosis of the homograft or nylon prosthesis were demonstrated in this manner. There was 1 instance of thrombosis which occurred between 6 weeks and 3 months; the remainder occurred prior to the first aortogram. Slight indentation at the site of suture lines was seen on most of the aortograms; however, except for the 1 case mentioned there was no progression of narrowing in any of the survivors. Nor has there been an instance of aneurysmal dilatation of the aorta in any of the animals. All 56 survivors were followed up for 6 to 12 months. Twenty-eight animals, 16 with nylon prostheses and 12 with homografts have been followed from 24 to 48 months. Figures 5 and 6 are typical aortograms 12 and 18 months after homograft and nylon prosthesis insertion.

TABLE I.—OVER-ALL INCIDENCE OF THROMBOSIS

| | *Synthetic prosthesis* | | *Homografts* | |
|---|---|---|---|---|
| | *No.* | *Per cent* | *No.* | *Per cent* |
| Surviving animals | | | | |
| Infection groups | 2 of 25 | 8 | 3 of 16 | 20 |
| Controls (without infection) | 1 of 10 | 10 | 1 of 10 | 10 |
| Dead animals (with infection) | 9 of 35 | 21 | 13 of 44 | 30 |
| All animals | 12 of 70 | 17 | 17 of 70 | 24 |

*Thrombosis.* In Table I the experience with thrombosis is summarized. It should be recalled that the internal diameter of the homografts and nylon prostheses employed was 7 to 9 millimeters. In the survivors there is little difference in the incidence of thrombosis in the infection groups and the control groups without infection. There was a higher incidence of thrombosis in the animals which died; however, these were primarily animals dying of hemorrhage and it was difficult to be certain that the thrombi had formed antemortem. When thrombus was present, it was invariably found to be adherent at one or both suture lines. In the total of 29 instances of thrombosis there were only 4 in which narrowing of the aortic lumen at the suture line was believed to have contributed to or caused the thrombotic occlusion.

*Peritonitis.* In spite of efforts to localize the infection to the retroperitoneal space, a rampant peritonitis frequently occurred in both homografted and nylon prosthesis animals. Twenty-three of the 35 deaths in the nylon prosthesis groups were due to overwhelming peritonitis. It should be noted

TABLE II.—ANALYSIS OF DEATHS DUE TO HEMORRHAGE

| | —Homograft— | | —Synthetic— | |
|---|---|---|---|---|
| | *No.* | *Per cent* | *No.* | *Per cent* |
| Disruption of suture line* | | | | |
| Host aorta | 0 | 0 | 12 | 100 |
| Graft | 22 | 60 | 0 | 0 |
| Rupture of graft | 15 | 40 | 0 | 0 |

*Indicating whether failure was due to sutures pulling out of graft or host aorta.

that aortic continuity was maintained in all of these animals; the 9 instances of thrombosis were found in the animals which died of exsanguinating hemorrhage. There were 8 instances of fatal peritonitis in the homografted animals and in only 1 of these had thrombosis occurred. Animals which died of exsanguinating hemorrhage also revealed gross and microscopic evidence of extensive peritonitis.

*Site of break in aortic continuity.* It was of interest to note the point of break in aortic continuity when an animal died of an exsanguinating hemorrhage. With a homograft, the breakdown occurred in one of three ways: (1) rupture of graft, (2) disruption of sutures from homograft, and (3) disruption of sutures from host aorta (Figs. 2, 3, and 4). With a nylon prosthesis, breakdown in aortic integrity was limited to sutures pulling out of the host aorta. In Table II is listed the frequency of each of these occurrences. The different modes of break in aortic integrity in the two groups may account for the longer survival time of the animals with nylon prostheses which eventually died. It may require longer for disruption of sutures to occur in the host aorta, which is viable growing tissue, whereas a freeze-dried homograft is completely nonviable. Another fact of interest regards the cases of fatal hemorrhage which occurred in animals with thrombosed grafts. In 9 of the 12 animals with nylon prostheses which bled to death, the exsanguinating hemorrhage occurred proximal to a thrombosed graft. In 7 of the 37 homografted animals which died of exsanguinating hemorrhage there was thrombosis of the graft.

*Evidence of residual infection.* Nylon prostheses and freeze-dried homografts are both foreign bodies when used for aortic replacement. As such, it is conceivable that they might serve as a nidus for prolonged and persistent infection. As would be expected, animals which died within the first week or two after graft implantation usually revealed persistent bacterial infection. The long term survivors were of greater interest in evaluating persistent or residual infection. Long term survivors which were sacrificed during the course of the study were closely studied for evidence of infection. In addition, all other survivors were re-explored 6 to 18 months after graft implantation. The grafts were exposed and the surrounding tissue examined and cultured for evidence of bacterial infection. In the 16 homograft survivors there was no evidence of persistent infection. In the 25 nylon prosthesis survivors there were 5 instances of purulent material pocketed around the nylon graft. This was discovered 6 weeks to 6 months after graft implantation. Bacterial cultures revealed growth of Escherichia coli in 3 of the 5 instances. In the other 2 instances no bacterial growth was obtained. In 2 of the 3 instances of proved bacterial infection the nylon prosthesis was thrombosed.

*Autopsy studies.* Routine autopsy was performed on all animals which died or were sacrificed. There was no evidence of nephropathy due to neomycin in any of the animals receiving that drug. There was 1 instance of fatal hemorrhage due to necrosis of the wall of the vena cava; this was thought to be due to infection and trauma to the vena cava in the course of graft insertion.

In animals with nylon prostheses which have been sacrificed, the fibrous tissue reaction around the prosthesis has been of interest. If the nylon graft was patent and free of thrombosis, there were two grossly separable layers surrounding the prosthesis. The external layer was 2 to 3 millimeters thick. Microscopically, this layer revealed connective tissue containing many small blood vessels. The external layer was loosely adherent to an inner layer which covered the nylon prosthesis. The inner layer was

very thin, smooth, glistening, and transparent. There was no evidence of fluid between the two layers. The inner layer resembled endothelium on microscopic study. A similar layer was found lining the inside of the nylon prostheses and the homografts. Three to 6 months after implantation a true intimal layer was found to be growing inward from each suture line into the homograft or nylon prosthesis. Even after 4 years this true intimal layer was never found to have progressed more than a centimeter from each suture line. We have not observed an instance in which the intimal layer completely lined the homograft or prosthesis.

Microscopic examination of the homografts which have ruptured secondary to infection revealed acute and chronic inflammatory cells in the aortic wall and disintegration of the elastic tissue layers extending out from the site of rupture. Similar findings are seen at the suture line, when that has been the site of breakdown. This destruction of elastic tissue is less marked on the host aortic side even when this has been the site of disruption of sutures. The inflammatory reaction in the host aorta appeared similar whether the implant had been a homograft or nylon prosthesis. Elastic tissue was still demonstrable in the homografts as long as 4 years after implantation.

## DISCUSSION

It is apparent that arterial replacement in the presence of infection is likely to fail in a high percentage of instances. There are several therapeutic measures to aid in the eradication of the infection and promote survival that were not employed in this study (i.e., surgical drainage, parenteral fluids, and blood transfusions).

In this study an attempt was made to find a preparation that would allow differences in the performance of freeze-dried homografts and synthetic prostheses as arterial substitutes to be delineated. Group I of the infection series proved to be an excessively severe test as 95 per cent of all the animals died. In group IV there was 90 per cent survival with functioning arterial substitute with both homograft and synthetic prosthesis. This observation seems to indicate that it is possible to neutralize the infection with sufficient antibiotic therapy. In groups II and III a difference in the performance of the homograft and synthetic substitute appeared. In these groups 45 per cent of the animals with synthetic prostheses survived as compared with 17 per cent survival in the animals with homografts. The deaths which occurred in the synthetic prosthesis groups were largely due to overwhelming peritonitis even though the aortic substitute was patent and functioning well. An extensive peritonitis also existed in the animals of both groups which died of an exsanguinating hemorrhage. In assessing maintenance of aortic integrity, it seems permissible to omit those animals which died of peritonitis alone. On this basis, the superiority of the synthetic prosthesis becomes far more significant. In Table III groups II and III are combined, with those animals which died of peritonitis omitted. Survival in the nylon prosthesis groups far exceeds that in the homografted animals. There were 2 failures in each group due to thrombosis. Thus, 64 per cent of the animals with nylon prostheses survived with functioning aortic substitute as opposed to 17 per cent for the homograft series.

TABLE III.—SUMMATION OF GROUPS II AND III WITH ANIMALS WHICH DIED OF PERITONITIS OMITTED

| | *Homograft* | | *Synthetic* | |
|---|---|---|---|---|
| | *No.* | *Per cent* | *No.* | *Per cent* |
| Animals | 31 | | 22 | |
| Fatal hemorrhage | 26 | | 6 | |
| Survivors | 6 | 19 | 16 | 73 |
| Survivor thrombosis | 2 | | 2 | |

The superiority of the synthetic prosthesis seems attributable to its greater strength. It will not decompose in the presence of bacterial infection as was produced in this study. On the other hand, the homograft will often disintegrate under these circumstances. This fact was emphasized by the

manner in which the homograft would rupture or fail to maintain integrity of suture line. The synthetic prosthesis did not rupture and uniformly held sutures. Animals with nylon prostheses suffered a break in aortic integrity only when the host aorta failed to hold sutures. It is likely that other synthetic prostheses would perform as well or better than the nylon tubing used in this study. Harrison and others have shown dacron and teflon to be far more durable than nylon.

The incidence of thrombosis of an aortic substitute in this study is quite similar to those reported by others working under sterile conditions. There was an increased incidence of thrombosis in the animals which died but it was difficult to be certain that the thrombus had formed antemortem. The over-all figures do not indicate that infection increased the likelihood of thrombosis. When performing anastomoses under sterile conditions with arteries 7 to 9 millimeters in diameter, others have encountered thrombosis in 10 to 20 per cent of the cases.

Even though the synthetic prosthesis proved to be the superior aortic substitute in the presence of infection, there was evidence that persistent, residual infection may occur with synthetic substitutes. Evidence of residual and persistent infection around the synthetic tube was found in 5 of 25 long term survivors. In 3 of the 5 instances a bacterial infection was proved to be present. It seems significant that in 2 of these 3 instances thrombosis of the nylon prosthesis had occurred. However, the undesirable aspects of chronic residual infection do not seem to outweigh the chance of acute disintegration of a homograft in the presence of infection.

It seems noteworthy that in the 24 to 48 month follow-up studies there was no evidence of aneurysmal dilatation of the homografts or synthetic prostheses. Nor was there evidence of thrombosis or stenosis at suture lines after the first 3 months by aortographic observation. Intramural calcification and lipid deposits have been noted in both homografts and nylon prostheses 3 to 4 years after implantation.

SUMMARY

The performance of freeze-dried homografts and seamless nylon tubing as aortic substitutes in the presence of bacterial infection has been evaluated.

The synthetic prosthesis proved superior both in terms of survival and maintenance of aortic continuity.

The factors responsible for this superiority have been discussed. It has also been noted that persistent residual infection may be found in the long term survivor with a synthetic prosthesis.

In follow-up studies of from 24 to 48 months' duration there has been no evidence of aneurysmal dilatation of the aorta, nor has there been aortic narrowing in the long term survivors.

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# SURGICAL ANATOMY OF THE SUBCLAVIAN ARTERY AND ITS BRANCHES

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THE VARIATIONS and anomalies of the subclavian artery and its branches can best be explained on the basis of the embryologic development of this segment of the vascular network. Developmentally, the subclavian artery and its branches convincingly illustrate the capacity of the blood stream to mold into a unit various channels, as the need arises. In a monumental work, Congdon has traced the development of the subclavian arteries from the paired seventh dorsal segmental arteries. He has attributed their migration cephalad to the anchoring effect of the vertebral arteries that moor this portion of the vascular tree during the caudal descent of the aorta. Carney has stated: "Once any particular segment of the aortic arch system ceases to function in carrying a portion of the blood stream, that segment is destined to disappear, but as long as it continues to function, it does not undergo degeneration from any cause." However, a secondary factor of tension thrown on particular segments due to descent of the aorta may play a role in its failure to function. Thus the interruption of the right aortic arch close to the bifurcation of the thoracic aorta occurs because the major portion of blood to the right upper extremity is passing by way of the aortic arch and fourth dorsal segmental artery at a time when the descent of the aorta places a tension on the distal portion of the right aortic arch. Portions of the aortic arch and of the right fourth dorsal segmental artery thus come to form the more proximal portion of the right subclavian artery, the right seventh dorsal segmental artery contributing only to its more distal portion. When this small segment of the right aortic arch distal to the seventh dorsal segmental branch fails to obliterate, then degeneration of the more proximal portion of the aortic arch and right fourth dorsal segmental artery occurs, leaving an anomalous right subclavian artery, which arises from either the more distal portion of the aortic arch or from the descending aorta, and usually crosses over the vertebral column posterior to the esophagus and trachea before eventually attaining its normal position.

The vertebral arteries, which play such a fundamental role in anchoring the developing subclavian vessels during the descent of the aorta, are also subject to anomalies based on variations occurring in the process of their development. It is believed that the cervical portion of the vertebral arteries is formed by a series of longitudinal anastomoses between the upper 7 dorsal segmental arteries. Usually the proximal portions of the upper 6 dorsal segmental arteries entering into this anastomosis disappear, thus leaving the vertebral artery as a branch of the subclavian trunk. However, should the proximal stem of the incorporated sixth dorsal segmental artery persist, then the right vertebral artery will take its origin from the common carotid trunk, while on the left the vertebral artery will arise as a branch of the aortic arch proximal to the left subclavian artery. Similarly, variation in the remaining branches of the subclavian artery can also be best explained on the basis of changes occurring in their developmental processes. As in a previous article, an attempt will be made to depict the possible variations for each arterial branch studied.

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The incidence of each of the anomalies encountered will thus be recorded. The reader will thereby be furnished with pictorial evidence of the accumulated statistics.

## MATERIAL AND METHODS

In the course of the present study, dissections were performed on 400 laboratory specimens, and for each dissection a drawing was made of the subclavian artery with all of its existing branches. Since much of the material was obtained as the result of student dissections, certain branches may have been destroyed prior to examination. In such cases the destroyed vessels were not included in the data. For this reason, no figures will be presented concerning the absence of certain of the arterial branches. In addition to the sketches of the subclavian artery and its branches, in 62 specimens detailed drawings and studies were prepared to illustrate the arterial branches which supply the cervical and upper thoracic portions of the esophagus. The arterial supply of the thyroid gland, including the superior thyroid vessels, was also studied in detail. Finally, measurements were taken and sketches were made of certain relations of the subclavian artery to the brachial plexus in the interscalene space and to the apex of the pleura.

## THE SUBCLAVIAN ARTERY

As we have seen, the 2 subclavian arteries originally arose symmetrically from the right and left aortic arches as the lateral seventh cervical segmental branches. With the disappearance of the lower part of the right aortic arch, an asymmetric picture develops. The subclavian artery on the right arises from the innominate trunk, while on the left side it springs directly from the aortic arch. Embryologically, a portion of the original right aortic arch is retained to form the innominate artery and a small part of the adult right subclavian artery. Thus the right subclavian artery is a little more than equivalent to its fellow of the opposite side. As a result of their difference in origin, a topographic asymmetry of the vessels results.

The subclavian artery is usually described as consisting of 3 portions. The first portion extends from its origin to the inner edge of the scalenus anterior muscle, the second portion lies behind that muscle, while the third portion extends from the outer border of the scalenus anterior muscle to the lower border of the first rib. Due to the difference in their origins, the relations of the first portions of the right and left sides differ somewhat. In the present study, variations in the relations of the subclavian artery on either side to the structures of the mediastinum were not studied in detail; therefore, such descriptions will be left to the standard textbooks of anatomy.

Of the 400 specimens examined, a single example of an anomalous right subclavian artery was encountered. This vessel (Fig. 1c) arose as a branch of the proximal portion of the descending aorta. It then coursed upward and to the right, crossing anterior to the third dorsal vertebra and posterior to the esophagus, to reach, eventually, the right mediastinum and there assume its normal course. Holzapfel, in a study which included 133 such specimens, found the artery crossed posterior to the esophagus in 107 of the cases, between the esophagus and trachea in 20 specimens, and in front of the trachea in 6 of the bodies. Frequently, an aneurysmal dilatation is found to involve the first part of this artery just above its origin from the aorta.

Another arterial variation, not primarily of the subclavian arteries but of the aortic arch, in which a right aortic arch exists with the left subclavian artery arising as the last major vessel from the arch and then crossing from right to left behind the esophagus (Fig. 1f), might easily be confused on roentgen examination with the anomalous right subclavian artery described.

Robert Gross (14-16) has thoroughly reviewed the surgical importance and therapy of the anomalous right subclavian artery, and of the right aortic arch with the left

subclavian artery arising last from the arch and crossing behind the esophagus. In the majority of such cases, these anomalous vessels passing posterior to the esophagus do not give rise to sufficient symptoms to warrant surgical therapy. However, if pressure upon the esophagus is sufficient to cause hesitancy in swallowing or discomfort during deglutition, the so aptly named "dysphagia lusoria," then complete relief of symptoms can be obtained by simple ligation and division of the anomalous subclavian artery with its removal from the posterior mediastinum. Since the anomalous vessels usually give rise to no important branches in this region, surgical therapy is simple, direct, and usually quite safe.

In another specimen, a colored adult male, a bilateral malposition of the subclavian arteries was encountered with both of the arteries situated anterior, instead of posterior, to the anterior scalenus muscles, accompanied by the subclavian veins. According to Dolgo-Saburoff, this is a developmental anomaly of the musculature and should not be classified as a vascular variation.

The subclavian artery usually reaches its highest cervical level in the region of its second anatomic segment. Here the subclavian artery lies behind the anterior scalene muscle, separated from the subclavian vein by that structure. Anteriorly, the subclavian artery is covered by the skin, superficial fascia, platysma muscle, deep cervical fascia, clavicular head of the sternocleidomastoid muscle, phrenic nerve, and the anterior scalene muscle. Posterior to the artery is the apex of the pleura and lung, often covered by the scalenus minimus muscle, with its insertion into the fibrous Sibson's fascia or suprapleural membrane and a portion of the scalenus medius muscle. The authors were particularly concerned with the cervical level of the pleural apex as compared to the level of the anteriorly situated apex of the subclavian arterial arch.

In 30 specimens, on 55 sides, 28 right and 27 left, an attempt was made to determine the exact relationship between the apex of the pulmonary cupola and the adjacent arch of the subclavian artery. These relationships were determined by first recording the distance between the readily palpable carotid tubercle of the sixth cervical vertebra and the highest point of the subclavian arch. A second measurement was later recorded, after the apex of the pulmonary cupola could be clearly discerned, between the carotid tubercle and the apex of the cupola. These measurements were then compared so as to determine the exact level of the subclavian arterial arch as compared to that of the pulmonary cupola.

The apex of the arterial vascular arch and the apex of the pulmonary pleura were at exactly the same level in 7 of the 55 sides, 6 on the right and 1 on the left side.

In 14 of the sides examined, 8 right and 6 left, the apex of the subclavian arterial arch was situated above the level of the pulmonary cupola. The distance varied from .1 to 3.0 centimeters, the average being .61 centimeter. However, if a single specimen in which the distance between the apex of the arterial arch and pulmonary cupola was 3.0 centimeters, due chiefly to an aneurysm of the aortic arch, is excluded, then the maximal distance is reduced to 0.8 centimeter, and the average distance to .42 centimeter. Since the average diameter of the subclavian artery is greater than this latter figure, it can readily be seen that in the great majority of these cases the lower surface of the subclavian arch is below the level of the pleural apex.

In 34 of the 55 sides, the apex of the vascular arch was actually below the level of the pleural apex. This phenomenon occurred 14 times on the right as compared to 20 times on the left side. The distance between the levels of the pleural and arterial apices varied from .1 centimeter to 1.5 centimeters, with an average distance of .456 centimeter. Thus, in this largest group of specimens, the apex of the pleura was

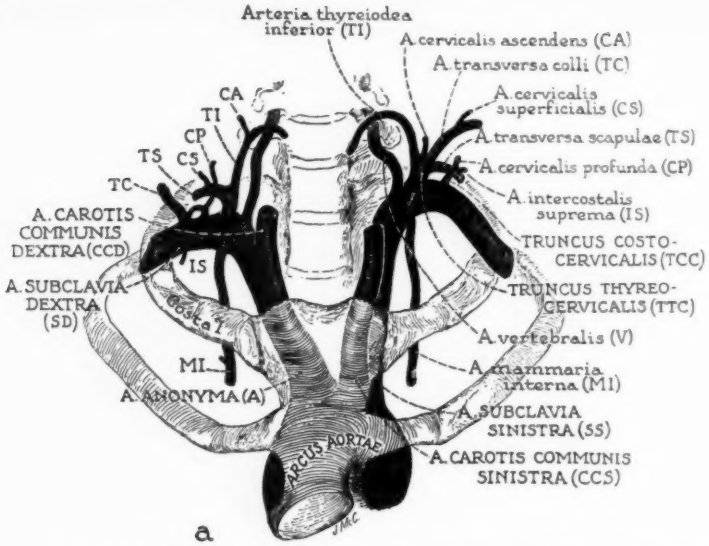



FIG. 1. Subclavian artery. a, The arterial trunks and branches covered in the current study, with each branch completely labelled on the left body-side and the abbreviated titles which will be hereinafter utilized depicted on the right body-side. b, The common vascular pattern encountered in 399 of the 400 bodies studied. On the right side the common carotid and subclavian arteries arise as branches of the innominate artery, while on the left they arise directly from the aortic arch. c, An anomalous right subclavian artery arises from the descending thoracic aorta distal to the left subclavian artery. d, In addition to the anomalous right subclavian artery, a bicarotid axis from which both the right and the left common carotid arteries take origin. e, An example of this same anomalous right subclavian artery arising from the descending aorta, but here associated with a left innominate artery. f, A right aortic arch with the left subclavian artery arising as the last branch from the arch, and crossing behind the esophagus en route to the left upper extremity. In the current series, no examples of the variations depicted in Figures 1d, 1e, and 1f were encountered.

actually at a higher cervical level than was the highest point of the subclavian arterial arch.

In nearly 3 out of 5 of the sides examined, the apex of the pleural cupola projected above the level of the arch formed by the subclavian artery. The pleural cupola is in this region situated posterior to the vascular arch and protected somewhat by Sibson's fascia, which in turn was reinforced by the scalenus minimus muscle in approximately 30 per cent of the cases.

This close proximity of the subclavian artery to the pleural cupola and pulmonary apex renders this vessel extremely liable to injury in procedures such as open and especially closed pneumolysis, necessitating the division of dense, fibrous adhesions between the parietal and visceral pleurae in the apical regions of the lung. The subclavian vessels are also liable to injury in the performance of thoracoplasties and other surgical procedures requiring resection of the first rib.

The subclavian artery and its branches play an important role in the surgical therapy of cervical ribs and the scalenus anticus syndrome. Adson has stated that three factors are responsible for the symptoms produced: (1) marked hypertrophy and thickening of the anterior scalene muscle with a broad insertion extending usually beyond the operculum of the first rib; (2) a long, cervical spinal column with a high-

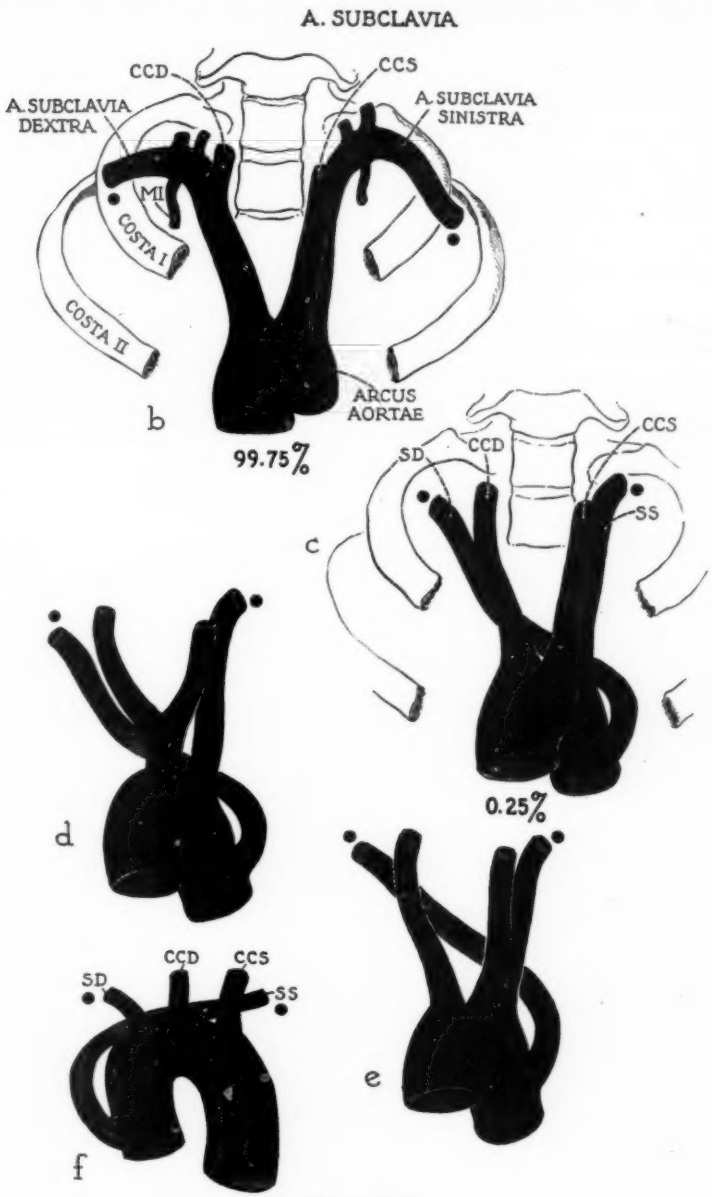



FIG. 1b to 1f.
*(Legend on facing page.)*

lying second division of the subclavian artery and a resultant narrowing of the space between the scalenus anticus, and the scalenus medius and posticus muscles; (3) if a cervical rib or a large transverse vertebral process is present, these bony structures elevate the floor of this space between the scalene muscles and displace the brachial

plexus forward against the subclavian artery. Adson has demonstrated that in the majority of such cases, symptomatology can be relieved by sectioning the scalenus anticus muscle. However, when a cervical rib or hypertrophic cervical transverse process occupies a high position, thus compelling the lower roots or trunks of the brachial plexus to ride up over it, then partial or complete removal of the cervical rib or transverse process is indicated.

In 100 of the sides studied, detailed drawings and measurements were made of the triangle bounded anteriorly by the scalenus anticus muscle, posteriorly by the scalenus medius and posticus muscles, and inferiorly by the upper surface of the first rib. The contents of this triangle, the subclavian artery and the roots and trunks of the brachial plexus, were also included in these sketches. These drawings and measurements were made in an effort to determine the normal anatomic variations encountered in this region. As far as we know, none of the subjects examined had suffered from the scalenus anticus syndrome.

The average length of the base of this interscalene triangle on the right side was 1.1 centimeters, and on the left side 1.2 centimeters, with a minimum length of but .1 centimeter and a maximum length of 2.2 centimeters. We can thus see that even in the so-called "normal" subject, the distance between the scalene muscles at the base of the interscalene triangle is not great and leaves but little room for passage of the subclavian artery and brachial plexus. The average length of the anterior side of this interscalene triangle was 7.1 centimeters as compared to an average length of 6.7 centimeters for the posterior side. The superior angle of this triangle is usually extremely acute.

The contents of the interscalene triangle were depicted in each of the 100 sides examined. In 60 the lower trunk of the brachial plexus, consisting of the combined eighth cervical and first thoracic roots, was situated at the base of the triangle posterior to the subclavian artery in the very limited space there available. In an additional 19 sides, the smaller first thoracic nerve root occupied this narrow cleft. In 31 of these extremities it was noted, in addition, that a transverse cervical branch from the second or third portion of the subclavian artery passed backward in such a manner as to ensnare the lower roots or trunks of the brachial plexus so that they could not possibly rise out of the narrow trough formed anteriorly by the subclavian artery, posteriorly by the scalenus medius and posticus muscles, and inferiorly by the upper surface of the first rib. It is indeed possible that these ensnaring transverse cervical vessels play a role in the production of the scalenus anticus syndrome.

Schumacker has described in detail the incisions and techniques used for exposure of the innominate and subclavian arteries and their branches. For the subclavian arteries he strongly recommends subperiosteal resection of segments of the clavicle, the segment to be removed depending upon the portion of the vessel to be exposed. Exposure of the innominate and proximal portions of the subclavian arteries is obtained by splitting the sternum in the midline down to the level of the second or third interspace and then transecting it at this level; the median third or half of the clavicle is also resected. At the completion of the vascular operative procedure, the clavicular periosteum is carefully sutured. These patients are then kept flat in bed on their backs for 2 or 3 weeks, with their shoulders held well back; a firmness will rapidly appear in the regions of the missing clavicular segments. When treated properly, they will have a normal shoulder configuration, normal motion, and will be entirely comfortable.

Recent progress in the surgery of congenital cardiovascular defects by Blalock (4, 5), Gross, and others has clearly shown the value of the rich and abundant collateral arterial supply to the upper extremities. Blalock, in close to 100 operations for pulmonic stenosis in which either the

innominate or subclavian artery was sacrificed, has found no significant interference with the circulation of the corresponding arm in any of these patients. The pulse may have been absent for a short time postoperatively, and the extremity slightly cooler than its mate of the opposite side, but there was never any question concerning the adequacy of the circulation to maintain the life of the part. Stephens has reported successful operations of this type on individuals 30 and 35 years of age. It thus becomes evident that the arterial branches of the subclavian and axillary arteries have sufficient collateral anastomotic connections to maintain successfully the life of the extremity when the subclavian artery has been severed and ligated in any of its 3 anatomic divisions, provided most of its branches and their rich anastomotic connections remain intact. However, one must also consider the possibility, in cases of ligated subclavian arteries, that there may be sufficient arterial blood to support life and meet normal demands but be inadequate for the increased demands of heavy physical labor or athletic endeavors.

### THE VERTEBRAL ARTERIES

Considering their complex embryologic development, it is surprising to learn that the vertebral arteries are the most constant of the subclavian branches. The vertebral artery is usually described as arising from the upper, posterior surface of the subclavian artery ½ to 2 centimeters medial to the thyrocervical trunk (Fig. 2a). The vessel then courses upward and somewhat posteriorly, situated between the longus colli and scalenus anticus muscles in front of the transverse process of the seventh cervical vertebra, to enter eventually the foramen in the transverse process of the sixth cervical vertebra. During the extravertebral portion of its course, the artery is surrounded by a plexus of sympathetic nerve fibers, crossed in front by the inferior thyroid artery and covered anteriorly by the vertebral and internal jugular veins. On the left side, in addition to these, the terminal portion of the thoracic duct crosses from medial to lateral, anterior to the vertebral artery.

Branches of the vertebral artery are rare in its first portion. In 5 specimens, 4 on the right and 1 on the left side, the inferior thyroid artery arose as a branch of the vertebral artery (Fig. 4d). In 5 specimens, 3 on the left and 2 on the right side, the costocervical trunk arose as a branch of the vertebral artery (Fig. 10h).

These figures on the occurrence and variations of the vertebral arteries agree in the main with those compiled by Chanamirjan and Iyer.

In 379 bodies, detailed studies were made of the site of entrance of the vertebral arteries into the foramina of the transverse processes of the cervical vertebrae. In 41 specimens, 5.41 per cent, 16 on the right and 25 on the left side, the vertebral artery entered the foramen in the transverse process of the seventh cervical vertebra. In 663 of the 758 sides examined, 87.46 per cent, 337 on the right and 326 on the left, the vertebral artery entered the foramen at the level of the sixth cervical vertebra. In 50 of the sides, 6.6 per cent, 23 on the right and 27 on the left, the vertebral artery ascended to the level of the fifth cervical vertebra before entering the foramen of its transverse process. In 5 specimens, 3 right and 2 left, the vertebral artery rose to the level of the fourth cervical vertebra before entering the foramen. Yazuta has pointed out that in approximately 50 per cent of cases in which the vertebral artery ascends to a level above the sixth cervical vertebra before entering its foramen, the inferior thyroid artery will cross beneath or dorsal to this anomalous vertebral trunk. This is particularly true when the origin of the vertebral artery is also anomalous, as from the aorta (Fig. 2d), innominate (Fig. 2d), or common carotid arteries (Fig. 2e).

A surgeon unaware of this relatively common variation might well encounter serious or even fatal hemorrhage and do untold damage to such important adjacent struc-

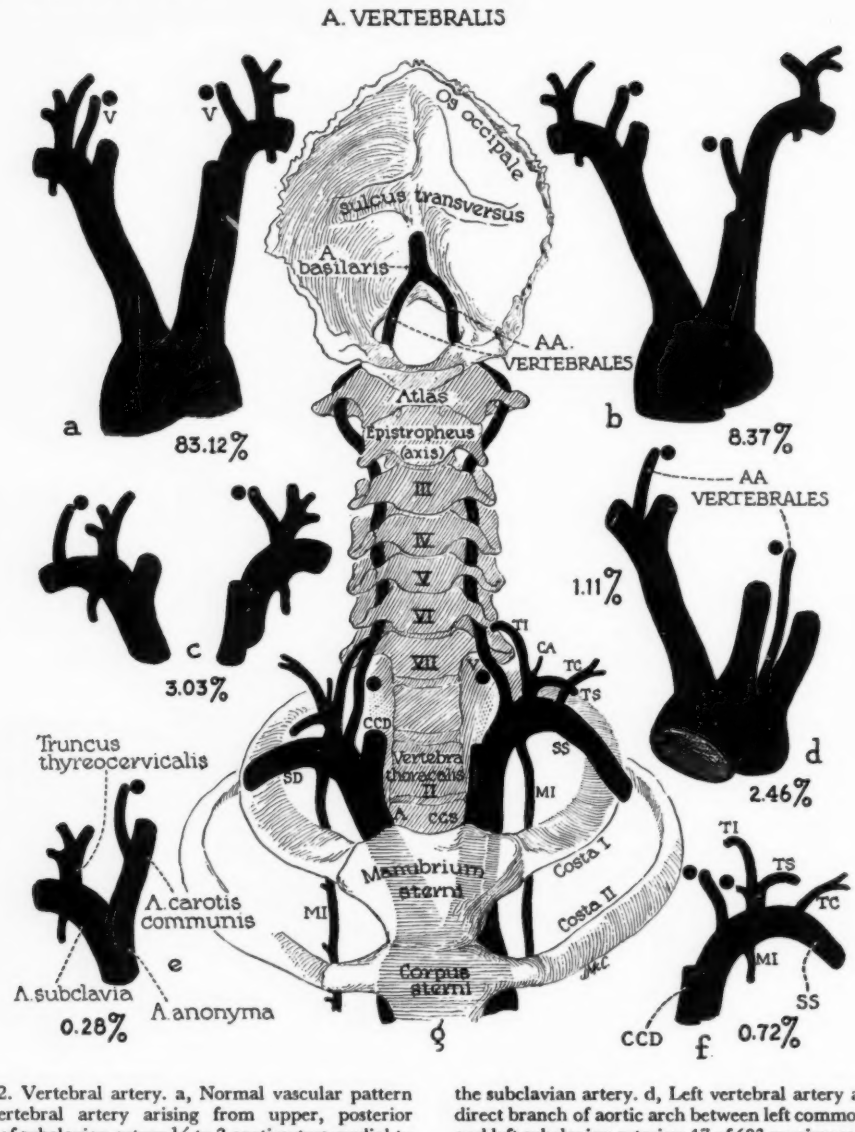



FIG. 2. Vertebral artery. a, Normal vascular pattern with vertebral artery arising from upper, posterior surface of subclavian artery ½ to 2 centimeters medial to thyrocervical trunk (also Fig. 2g); 576 of 693 specimens, 83.12 per cent. b, Vertebral artery displaced more than 2 centimeters medial to the thyrocervical trunk but still derived from subclavian artery; 58 of 693 specimens, 8.37 per cent; 25 right, 33 left. c, Vertebral artery arises from subclavian artery lateral to or as common trunk with thyrocervical trunk; 21 of 693 specimens, 3.03 per cent; 17 right, 4 left. In all of these cases the vertebral artery arose from a common stem with the thyrocervical trunk on the left side. In only 3 of these specimens did the right vertebral artery arise as a branch of the second portion of the subclavian artery. d, Left vertebral artery arising as direct branch of aortic arch between left common carotid and left subclavian arteries; 17 of 693 specimens, 2.46 per cent. Right vertebral artery arising at site of bifurcation of innominate artery into right subclavian and right common carotid arteries; 7 of 693 specimens, 1.11 per cent. e, Right vertebral artery arising as direct branch of right common carotid artery; 2 of 693 specimens, 0.28 per cent. f, Dual or accessory vertebral arteries were encountered in 5 of 693 specimens, 0.72 per cent; all were left-sided. Three small accessory vertebral arteries arose as direct branches of the aortic arch, and 2 as a branch of the thyrocervical trunk. In all cases, the larger or main vertebral artery arose from the left subclavian artery.

tures as the brachial plexus, thoracic duct, common carotid artery or jugular vein if this vessel were accidentally torn or severed while attempting to mobilize or ligate the inferior thyroid artery as it crosses beneath the carotid sheath in doing a thyroidectomy, or attempting to excise a pharyngeal diverticulum.

Elkin and Harris have made a comprehensive survey of the anatomic and surgical problems encountered in the treatment of aneurysms and arteriovenous fistulas of the vertebral vessels. They have recommended that the cervical portion of the vertebral vessels first be identified and made ready for ligation, if necessary, as a preliminary step in operations on the vessels elsewhere in their course. Ligation here will only diminish and not completely control hemorrhage elsewhere in the vertebral system because of its rich anastomotic connections; however, it will at least prevent an alarming and critical blood loss. These authors have described in detail the techniques of exposure and treatment of fistulas of the second and third portions of the vertebral vessels. Suffice it to say that actual excision of the fistula is impossible in the great majority of cases because of the difficulties encountered in obtaining adequate exposure of the vessels involved. Obliteration of the fistula was usually accomplished by proximal and distal ligation of the involved vessels, followed by the placing of mass suture ligatures in the region of the fistulous tract.

The technical difficulties of injecting the vertebral artery for purposes of angiography have been discussed in an article by List, Burge, and Hodges. Of the two techniques offered by these authors, direct puncture of the vertebral artery before it enters the transverse process of the sixth cervical vertebra would seem the more satisfactory. One of the dangers of this procedure seems to be the possibility of creating an arteriovenous fistula through injury to the vertebral vein, which lies on the anterior surface of the artery in very close proximity to it.

Their second method of vertebral perfusion indirectly through retrograde injection into the subclavian artery seems far less satisfactory through loss of the injected opaque material into the carotid system, and via the internal mammary and costocervical branches of the subclavian artery. This procedure is also not innocuous because danger of injury to the pleural cupola, subclavian, jugular, and innominate veins and thoracic duct must constantly be guarded against.

It would seem that the simplest procedure anatomically is one in which the contrast media is injected directly into the third portion of the vertebral artery as it winds behind the superior articular process of the atlas in the suboccipital triangle of the neck. With practice, this can be accomplished without surgically exposing the vessel. However, in a recent communication from James L. Poppen, from whom we learned of the procedure, it is stated that there is greater hazard associated with its use than with the simpler anterior approach (which latter he has adopted).

### THE THYROCERVICAL TRUNK OR THYROID AXIS

The most variable of the major branches of the subclavian artery is the thyrocervical trunk. De Garis, Bean, Thomson, and Adachi have classified the branches of the subclavian artery on the basis of variations occurring in the derivation of branches from the thyrocervical trunk. Textbooks of anatomy usually describe the thyrocervical trunk or thyroid axis as a short, thick trunk arising from the upper and front part of the subclavian artery opposite the origin of the internal mammary artery and near the medial edge of the anterior scalene muscle. It is said to divide almost immediately into three radiating branches: (1) the inferior thyroid; (2) transverse scapular; and (3) superficial cervical arteries. This typical textbook arrangement (Figs. 3, key, left, and Fig. 3a) was encountered in 360 of the 770 sides studied, 46.75 per cent.

For purposes of classification, variations in the branchings of the thyrocervical trunk were divided into 6 main types, based

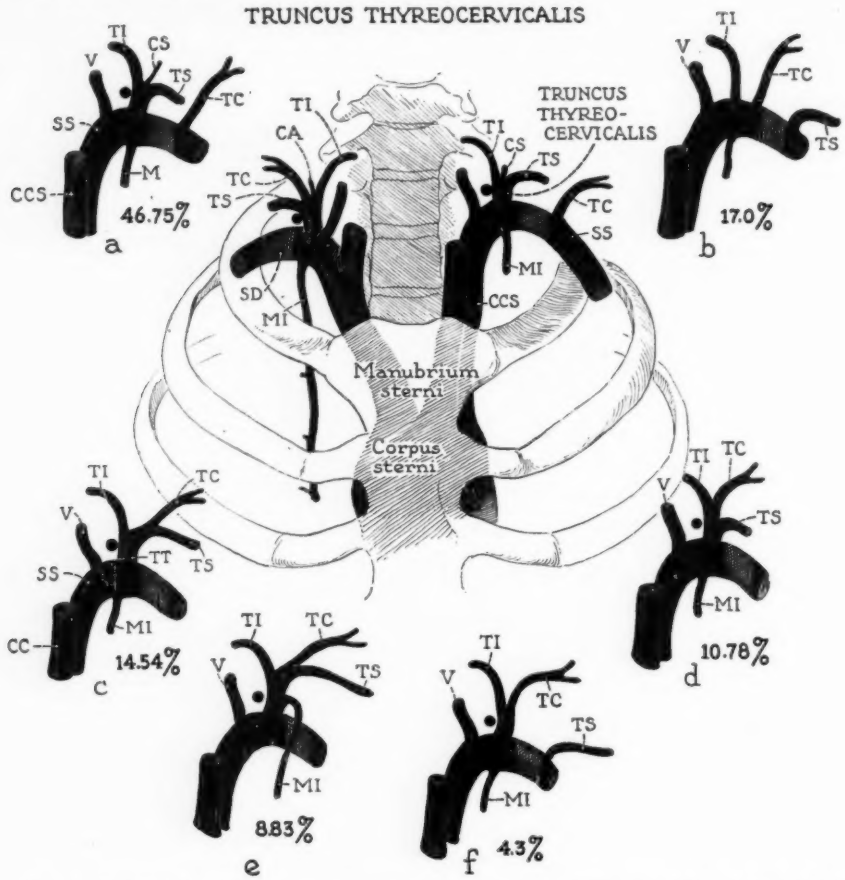



FIG. 3. Thyrocervical trunk. a, Transverse cervical directly from subclavian artery (Figs. 3 key, left, 3a); 360 of 770, 46.75 per cent; 180 right, 180 left. b, Absence of thyrocervical trunk (Figs. 3b, 5d, 7d; 131 of 770, 17 per cent; 74 right, 57 left. c, Transverse scapular and cervical from common trunk off thyrocervical; 112 of 770, 14.54 per cent; 54 right, 58 left. d, Separate origins of branches from thyrocervical trunk (Figs. 3 key, right, 3d); 83 of 770 specimens, 10.78 per cent; 52 right, 31 left. e, Internal mammary from thyrocervical trunk; 68 of 770, 8.83 per cent; 11 right, 57 left. f, Transverse scapular arising separately from subclavian; 33 of 770, 4.3 per cent; 12 right, 21 left.

chiefly upon the derivation of the inferior thyroid, transverse scapular, and transverse cervical arteries. The superficial cervical was not utilized in this classification, inasmuch as a great deal of confusion exists concerning this particular branch. An additional type was added, based upon the frequency of origin of the internal mammary artery from the base of the thyrocervical trunk (Fig. 3e). This classification is slightly more complex than that offered by Bean, but is also much more inclusive. On the other hand, it does not approach in complexity the classifications of De Garis and Thomson, which, in our opinion, are too complicated for practical use.

In order to ascertain the usual point of origin of the thyrocervical trunk, when it is present, measurements were taken of the length of the subclavian artery from its origin to that point at which the thyrocervical trunk arose. These measurements were

performed in 132 of the sides, 88 on the right and 44 on the left side. The average distance of the subclavian artery from innominate to origin of the thyroid axis was 2.35 centimeters, with the greatest distance being 3.5 centimeters, and the least distance being 1.0 centimeter. The left thyrocervical trunk arose an average distance of 4.40 centimeters from the base of the subclavian artery, the maximal distance being 5.6 centimeters, whereas the minimal distance was but 3.0 centimeters. It can thus be seen that the site of origin of the thyrocervical trunk from the subclavian artery is much less variable than that of the vertebral or of the other major branches of the subclavian artery. When one considers that the distance between the extremes of origins of this vessel on the two sides is but 2.5 to 2.6 centimeters or 1 inch, its constancy of location is indeed amazing.

The length of the thyrocervical trunk proper, before it broke up into its constituent branches, was determined in 196 of the sides examined, 96 on the right and 100 on the left side. The right thyrocervical trunk averaged .86 centimeter in length, ranging from .1 to 3.8 centimeters. The left thyrocervical trunk was an average of .895 centimeter in length, with a maximum length of 3.7 centimeters, as compared to a minimum length of zero. In the 2 specimens conforming to this latter measurement, the length of the thyrocervical trunk could not be measured because it divided immediately upon origin into its separate branches.

Even though the thyrocervical trunk is absent in over 17 per cent of all cases, its constancy of location, when present, should make it useful as an anatomic and surgical landmark. When the thyrocervical trunk itself is absent, one of its major branches, usually the inferior thyroid artery, is commonly present at its usual site of origin. This vascular trunk could thus be of aid in orientation and helping to locate such surgically important structures as the lower roots and trunks of the brachial plexus, the phrenic nerve, the anterior scalenus muscle, and the thoracic duct.

### THE INFERIOR THYROID ARTERY

Surgically speaking, the most important branch of the thyrocervical trunk is the inferior thyroid artery. Much has been written concerning the embryologic and phylogenetic development of this vessel, its relationship to the recurrent laryngeal nerves, the parathyroid glands, the cervical sympathetic ganglia and plexus, and the vertebral arteries. Rogers is of the opinion that the superior thyroid artery is the primitive vessel supplying the gland because of its constancy, and also because in certain animals such as the rhesus monkey and chimpanzee, it forms the sole source of arterial supply. Weller, however, on the basis of extensive embryologic studies, has demonstrated that the primitive arterial supply of the thyroid gland in man is from inferior sources, first medial and then lateral in location. In the 16 millimeter embryo, large channels arising from the carotid arteries, the innominate artery, and the aortic arch form extensive ramifications among the cell groups of the median thyroid; only at a later period, in the 23 millimeter embryo, do the lateral components have a similar arrangement. Thus this hilar supply of arterial blood to the thyroid gland may retain its primitive connections with the carotids, aortic arch, or innominate artery, and become an anomalous inferior thyroid artery; they may be reduced in size and act only as accessory vessels, thus becoming thyroid ima arteries; or they may cease functioning, obliterate, and completely disappear.

The inferior thyroid artery, after its origin from the thyrocervical trunk or directly from the subclavian artery, ascends almost vertically to the level of the sixth cervical vertebra. It then turns medially and crosses behind the carotid sheath; finally it curves inferiorly before reaching the lower pole of the thyroid gland and breaking up into its terminal branches.

Dual inferior thyroid arteries, one branch usually accessory and of the thyroid ima type, were very unusual, occurring in but 6 of the 775 sides examined, 4 times on the

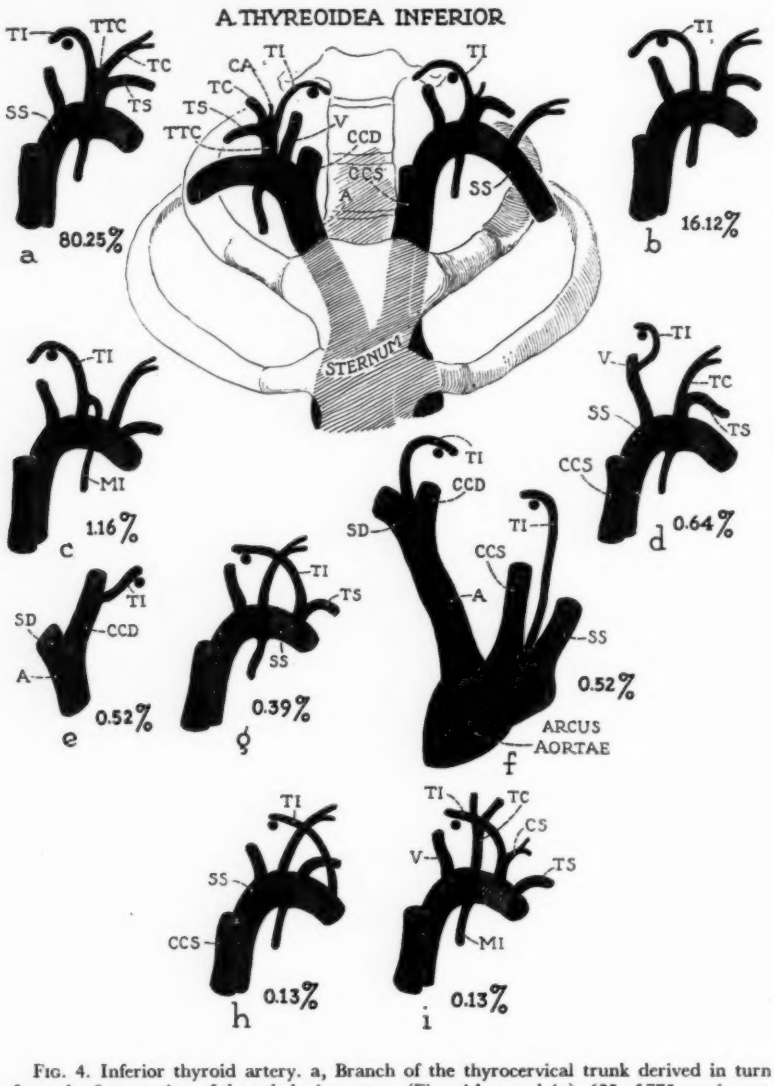



FIG. 4. Inferior thyroid artery. a, Branch of the thyrocervical trunk derived in turn from the first portion of the subclavian artery (Figs. 4 key and 4a); 622 of 775 specimens, 80.25 per cent; 301 right, 321 left. b, Separate and distinct branch from first portion of subclavian artery; 125 of 775 specimens, 16.12 per cent; 74 right, 51 left. c, Common trunk with internal mammary artery; 9 of 775 specimens, 1.16 per cent; 5 right, 4 left. d, Common trunk vertebral artery; 5 of 775 specimens, 0.64 per cent; 4 right, 1 left. e, Direct branch of common carotid artery; 4 of 775 specimens, 0.52 per cent; all on right side. f, Vessel of thyroid ima type, arising at bifurcation of innominate artery on the right, and from the aortic arch between the left common carotid and subclavian arteries on the left; 4 of 775 specimens, 0.52 per cent; 2 right, 2 left. g, Common trunk with transverse scapular artery derived in turn from third part of subclavian artery; 3 of 775 specimens, 0.39 per cent; 2 right, 1 left. h, Separate and distinct branch from third portion of subclavian artery; 1 of 775 specimens, 0.13 per cent; right side. i, Common trunk with costocervical trunk derived in turn from second portion of subclavian artery; 1 of 775 specimens, 0.13 per cent; right side.

right and 2 times on the left side, an incidence of .77 per cent. The inferior thyroid artery was also absent in 7 of the sides (.9 per cent) examined, and in all of these cases, on the left side. Owing to destruction of these vessels during student dissections, it is quite possible that the thyroid ima type of accessory inferior thyroid artery is more common than our figures would indicate.

The length of the inferior thyroid artery from its origin to the point of its division into terminal glandular branches was determined by measurements in 198 of the sides examined, 97 on the right and 101 on the left. The right inferior thyroid artery averaged 3.79 centimeters in length, the longest vessel being 6.7 centimeters, while the shortest measured but 1.5 centimeters. The left inferior thyroid artery was an average of 3.91 centimeters in length, with a maximum of 7.0 centimeters and a minimum of only .6 centimeter. This latter vessel arose as a short, thick branch from the thyrocervical trunk, and divided almost immediately into separate glandular branches.

Although variations of the inferior thyroid artery of surgical importance are quite rare (97 per cent of the vessels being derived from the thyrocervical trunk or from the first portion of the subclavian artery and following the usual course to the gland), it behooves the careful surgeon to recall that this vessel can arise from such diverse sources as the aortic arch, common carotid, innominate, vertebral, and more distal portions of the subclavian artery and its branches. It must also be remembered that when the vertebral artery has an anomalous point of entrance into the foramina of the cervical transverse processes, the inferior thyroid artery can be situated posterior to the vertebral artery.

The relations of the inferior or recurrent laryngeal nerve to the inferior thyroid artery are of extreme importance to surgeons treating thyroid disease in particular. Reed, in a series of 506 dissections, has listed 28 types of relations encountered. The complexity of types increases greatly when the vessel and nerve divide into terminal branches that intermingle during crossing.

The relations of the inferior thyroid artery and recurrent laryngeal nerve were studied in only 135 of the 775 sides in this series, 68 times on the right and 67 on the left side. The inferior laryngeal nerve crossed anterior to the artery or its branches in 39 specimens, or 28.88 per cent of the sides, 23 on the right and 16 on the left side. In another 48 specimens, 35.55 per cent, the recurrent laryngeal nerve passed between the terminal branches of the inferior thyroid artery, 25 times on the right and 23 times on the left side. It can thus be seen that in nearly two-thirds of the sides examined in this series, the inferior or recurrent laryngeal nerve was so situated as to be extremely liable to injury during radical thyroid surgery. The inferior laryngeal nerve passed posterior to the inferior thyroid artery or its branches in 44 of the sides, or 32.59 per cent, 19 on the right and 25 on the left side. In an additional 4 specimens, 1 on the right and 3 on the left side, the recurrent laryngeal nerve coursed entirely medial to the inferior thyroid artery and its terminal branches, thus failing to come into intimate relationship with the vessel or its branches at any point.

This intimate relationship of the recurrent laryngeal nerve to the inferior thyroid artery and its terminal branches is surgically so significant that Hertzler, Lahey (21), and others who have advocated total thyroidectomy for Graves' disease and cancer of the thyroid gland, have strongly advocated routine exposure and visualization of the recurrent laryngeal nerves throughout their cervical course before excision of the gland is attempted. On the basis of the present studies, this surgical step would seem wholly advisable.

Other surgeons, including Pemberton and Black at the Mayo Clinic, and Colcock at the Lahey Clinic, practice ligation of the inferior thyroid artery in continuity as it passes medialward beneath the carotid sheath. This practice could easily result in

injury to an anomalous vertebral artery or vein, were the presence of either unrecognized.

During the latter stages of the present study, detailed dissections were made in 62 bodies (115 body halves), concerning the arterial supply to the cervical and upper thoracic portions of the esophagus and trachea. The pharynx, esophagus, and trachea are usually supplied by several very fine arterial twigs from the terminal branches of the inferior thyroid arteries. Although these arterial branches are quite small in size, they are usually multiple in number, ranging from 1 to 4 on either side. These branches may pass directly to the esophagus and trachea, or may pursue a long and devious course downward into the superior mediastinum, before breaking up into their terminal branches. As a rule, this terminal branching occurs in the region of the groove formed between the trachea and esophagus, with the terminal twigs supplying the adjacent surfaces of both structures.

Single arterial branches were present 31 times on the right side and 27 times on the left. Dual arterial branches were found 18 times on the right and 21 times on the left. Triple arterial twigs were encountered on 15 sides, 8 on the right and 7 on the left, while quadruple branches were present on 3 left sides. Since many of the dissections were performed by our freshman medical students, it is possible that multiple branches occur much more frequently than is indicated by this study.

The arterial branches to the esophagus and trachea were derived from the distal half of the inferior thyroid artery 63 times on the right and 65 times on the left side. The esophageal and tracheal arterial branches originated from the proximal half of the inferior thyroid artery 20 times on the right and 23 times on the left side. These arterial branches took origin from the thyrocervical trunk proper, before its division into terminal branches, in 10 cases, 4 on the right and 6 on the left side. In 2 cases, 1 on each side, these arterial branches were derived from the costocervical trunk, whereas in 2 additional cases, 1 on either side, the arterial branches took origin from the first part of the subclavian artery. In 1 specimen, on the right, the arterial twig to the esophagus and trachea arose as a branch of the innominate artery, while in another specimen, also on the right side, this vessel arose as a direct branch of the common carotid artery. On the left side of this specimen, this twig arose as a branch of the vertebral artery, the inferior thyroid artery being absent. In another specimen, in which the inferior thyroid artery was also absent, a large, short trunk dividing into 4 separate twigs, arose as a branch from the common trunk of a vessel from which the superficial and ascending cervical arteries and transverse scapular artery took origin.

### THE TRANSVERSE SCAPULAR ARTERY

The transverse scapular or suprascapular artery usually arises from the thyrocervical trunk and curves laterally across the base of the posterior triangle of the neck. It lies at a somewhat lower level than the superficial cervical or transverse cervical arteries. In its course, it crosses anterior to the anterior scalene muscle and phrenic nerve, and then dips downward to lie behind the clavicle and subclavian muscle. At the lateral angle of the posterior triangle of the neck, it sinks beneath the posterior belly of the omohyoid muscle, to reach the scapular notch and pass above the ligament bridging that notch. It eventually supplies the supraspinatus and infraspinatus musculature of the scapula. There it establishes important anastomoses with the descending branch of the transverse cervical artery and circumflex scapular branch of the subscapular artery. These anastomoses form important collateral channels when it is necessary to ligate the second or third parts of the subclavian artery, or the axillary artery proximal to its subscapular branch.

The surgical significance of this vessel, as well as that of the transverse cervical artery, lies in its rather abundant anastomotic con-

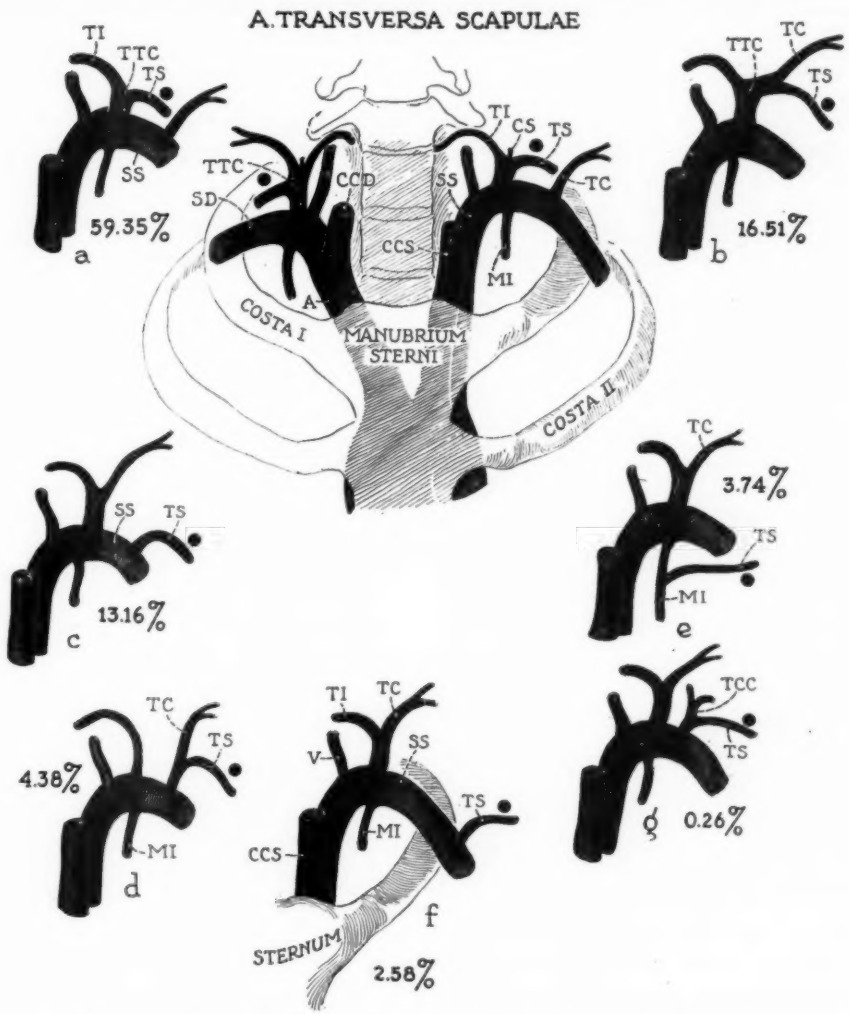



FIG. 5. Transverse scapular artery. a, Independent branch of thyrocervical trunk (Figs. 5 key, bilateral, and 5a); 460 of 775 specimens, 59.35 per cent; 236 right, 224 left. b, Common trunk with transverse cervical artery derived in turn from the thyrocervical trunk; 128 of 775 specimens, 16.51 per cent; 60 right, 68 left. c, Direct branch of the subclavian artery; 102 of 775 sides, 13.16 per cent; 53 right, 49 left. First portion subclavian artery, 51 sides; second portion, 8; third portion, 43. d, Common trunk with transverse cervical artery derived from subclavian artery; 34 of 775 extremities, 4.38 per cent; 20 right, 14 left. Branch of first portion subclavian, 12 specimens; second portion, 2; third portion, 20. e, Common trunk with internal mammary artery; 29 of 775 extremities, 3.74 per cent; 9 right, 20 left. f, Direct branch of the axillary artery; 20 of 775 sides, 2.58 per cent; 8 right, 12 left. g, From common trunk with costocervical trunk; 2 of 775 specimens, 0.26 per cent; both left.

nections. For this reason, either vessel may be ligated with impunity because the areas supplied by these vascular channels will receive adequate arterial blood from the deep and superficial cervical arteries, from connections with each other, and from anastomoses with branches of the axillary artery (chiefly the subscapular artery and

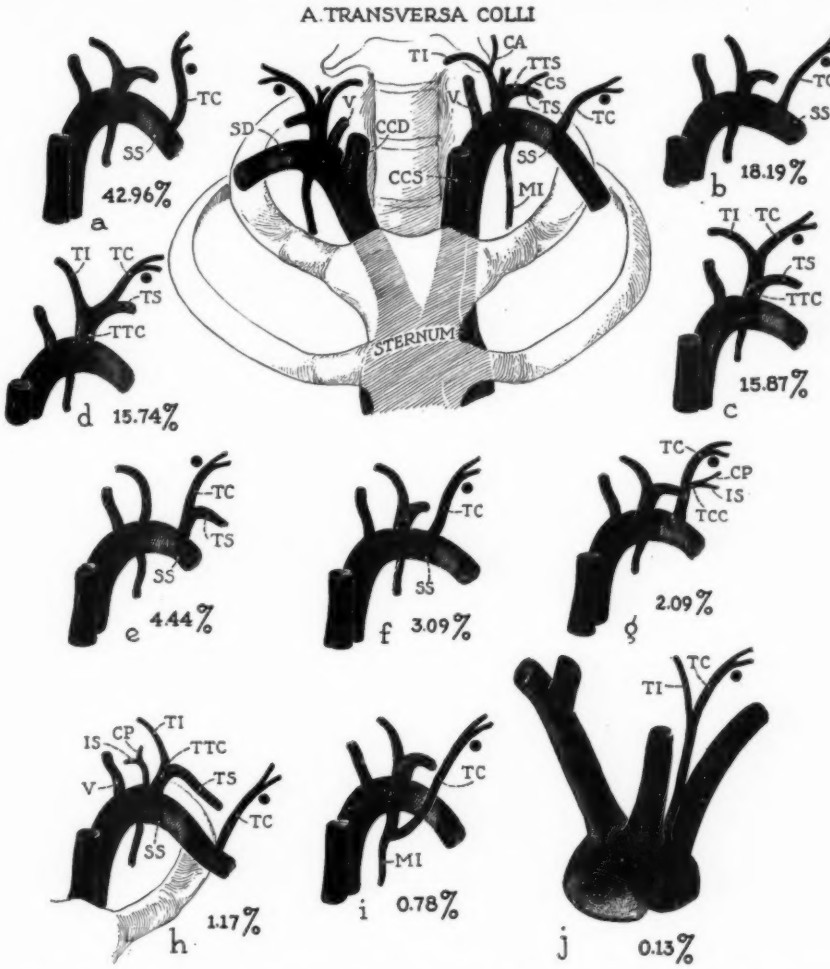
its deep circumflex scapular branch). These are also the channels which carry collateral arterial circulation when either the subclavian or the axillary arteries require ligation. In cases of severe trauma which necessitate ligation of the subclavian or axillary arteries, the thyrocervical trunk and its branches and the subscapular artery and its branches should be preserved if it is possible to do so. Collateral arterial flow through these channels may provide sufficient circulation to preserve the vitality of the involved extremity.

### THE TRANSVERSE CERVICAL ARTERY

The transverse cervical artery, in most of the recently published textbooks of anatomy, has been described as the only branch arising from the third portion of the subclavian artery. It then pursues an ascending course across the base of the neck, there being situated approximately midway between the upper superficial cervical and the lower transverse scapular arteries. The vessel usually courses either in front of or behind the scalenus medius muscle; frequently it pierces this muscle before attaining the lateral border of the levator scapulae, where it divides into its terminal ascending and descending branches. If a definite superficial cervical artery is present, this terminal ascending branch of the transverse cervical artery may be insignificant in size, or entirely absent. To the authors it seems inadvisable that a vessel destined to supply definite regions and structures be called transverse cervical if it originates from the subclavian artery, and superficial cervical when it takes origin from the thyrocervical trunk. Therefore, the authors have continued to refer to the transverse cervical artery as the principal vessel of supply to the vertebral border of the scapula and the superior cervical musculature. The name superficial cervical artery has been reserved for the vessel that supplies chiefly the trapezius, levator scapulae, and splenii. Regardless of nomenclature, the descending or posterior scapular branch of the transverse cervical artery forms its principal channel and originates most commonly as a direct branch of the subclavian artery, whereas the ascending or superficial cervical branch is its minor channel and arises most commonly from the thyrocervical trunk or one of its branches.

The transverse cervical artery usually originates from either the subclavian artery or from the thyrocervical trunk. The Europeans (Rohlic..) seem to find the transverse cervical artery arising more frequently from the subclavian artery, whereas the English anatomists (Thomson) have encountered it most commonly as a branch of the thyrocervical trunk. When the transverse cervical artery arises as a branch of the thyrocervical trunk, it always crosses anterior to the brachial plexus and scalenus medius muscle on its way to the lateral border of the levator scapulae and to the point of its terminal division into ascending and descending branches. However, the transverse cervical branch of the subclavian artery arches posterosuperiorly, coming into direct relationship with the roots and cords of the brachial plexus. This relationship will be discussed in detail in another paragraph.

The transverse cervical artery was duplicated in 41 of the sides examined (5.36 per cent), 17 times on the right and 24 times on the left side. These accessory transverse cervical arteries, although they also might well have been termed subscapular arteries, usually took origin in addition to the regular transverse cervical branch from the second or third parts of the subclavian artery. The vessel then passed in a posterior and inferior direction, passing beneath or inferior to the brachial plexus, eventually to supply the subscapular musculature and to form abundant anastomoses with the circumflex scapular branch of the subscapular artery, and the descending branches of the transverse cervical and transverse scapular arteries. These accessory or duplicated transverse cervical arteries were usually considerably smaller in size than the regular transverse cervical artery.




FIGS. 6. Transverse cervical artery. a, Direct branch from third portion of subclavian artery (Figs. 6 key, left, and 6a); 333 of 765 extremities, 42.96 per cent; 177 right, 156 left. b, Direct branch from second portion of subclavian artery; 140 of 765 extremities, 18.19 per cent; 70 right, 70 left. c, Independent branch from thyrocervical trunk; 122 of 765 sides, 15.87 per cent; 63 right, 59 left. d, From fused common trunk with transverse scapular artery. Common branch in turn derived from thyrocervical trunk; 121 of 765 sides, 15.74 per cent; 58 right, 63 left. e, From fused common trunk with transverse scapular. Trunk in turn arising from subclavian artery; 34 of 765 sides, 4.44 per cent; 20 right, 14 left. Twelve first portion, 2 second portion, 20 third portion of subclavian artery. f, As direct branch from first portion of subclavian artery; 24 of 765 sides, 3.09 per cent; 12 right, 12 left. g, From a common vessel with costocervical trunk (or deep cervical artery); 16 of 765 extremities, 2.09 per cent; 6 from first portion, 8 from second portion and 2 from third portion of subclavian artery. h, As a direct branch from the axillary artery; 9 of 765 sides, 1.17 per cent; 4 right, 5 left. i, Branch of internal mammary artery; 6 of 765 sides, 0.78 per cent; 2 right, 4 left. j, Branch of a thyroid ima artery derived in turn from aortic arch; 1 of 765 specimens, 0.13 per cent, left side.

In 104 of the extremities in the current series, detailed studies were made of the relationships between the transverse cervical branch of the subclavian artery and the roots and trunks of the brachial plexus.

In 53 of these extremities (50.96 per cent), 26 on the right and 27 on the left side, the transverse cervical artery coursed posteriorly, passing between the upper and middle trunks of the brachial plexus or between their constituent roots, the sixth and seventh cervical roots, on the way to the lateral border of the levator scapulae muscle. In a single specimen on the left side (1.0 per cent), the transverse cervical artery passed backward between the fifth and sixth cervical nerve roots.

In 45 of the extremities (43.27 per cent), 18 on the right and 27 on the left side, the transverse cervical artery penetrated the space between the inferior and middle trunks, or the space between the seventh and eighth cervical roots on the way to its destination.

Finally, in 5 extremities (4.8 per cent), 4 on the right and 1 on the left side, the transverse cervical branch of the subclavian artery passed inferior to all cords and trunks of the brachial plexus before attaining the upper end of the vertebral border of the scapula.

It should be noted here that in most cases in which the transverse cervical artery arose from the first or second portions of the subclavian artery, it passed posteriorly in relation to the roots of the brachial plexus, whereas in the cases originating from the third portion of the subclavian or axillary artery, the vessel was found to pass dorsalward in relation to the trunks of the brachial plexus.

The surgical importance of a transverse cervical branch that originates from any one of the 3 anatomic divisions of the subclavian artery and passes posteriorly in close relationship to the brachial plexus lies in its inaccessibility and the danger of its being torn in surgical maneuvers attempting to mobilize the subclavian artery. The senior author has seen 1 patient in whom this vessel was torn from its site of origin in the subclavian artery, leaving a large, gaping hole in the latter vessel during removal of a cervical rib. In order to control hemorrhage, it was necessary for the surgeon to double ligate the subclavian artery on either side of the opening. If the surgeon, in seeking the distal stump of the torn vessel, had used hemostats indiscriminately in the region of the plexus, even more serious damage might have been done.

### THE SUPERFICIAL CERVICAL ARTERY

The superficial cervical artery is a vessel concerning which there has been much confusion. It is usually described as a moderate to small vessel arising from the thyrocervical trunk and coursing transversely across the neck, passing beneath the sternocleidomastoid muscle to reach the posterior triangle of the neck, where it is superficially situated, covered only by the platysma muscle, cervical fascia, and skin. It eventually reaches the anterior margin of the trapezius muscle, where it divides into its terminal ascending and descending branches, supplying the musculature of the posterior cervical and scapular regions. It also forms important anastomotic connections with the deep and ascending cervical arteries, the descending branches of the occipital, transverse cervical, and scapular arteries.

In the present series, the superficial cervical artery usually existed as a separate and distinct branch only when the transverse cervical artery arose from a source other than the thyrocervical trunk. When the transverse cervical artery did arise from the thyrocervical trunk, the superficial artery was usually represented by a small branch of this vessel, the terminal ascending branch. However, in those cases in which the transverse cervical artery arose as a direct branch of the subclavian artery, or from a source other than the thyrocervical trunk, a well developed and distinct superficial cervical artery was usually found to be present.

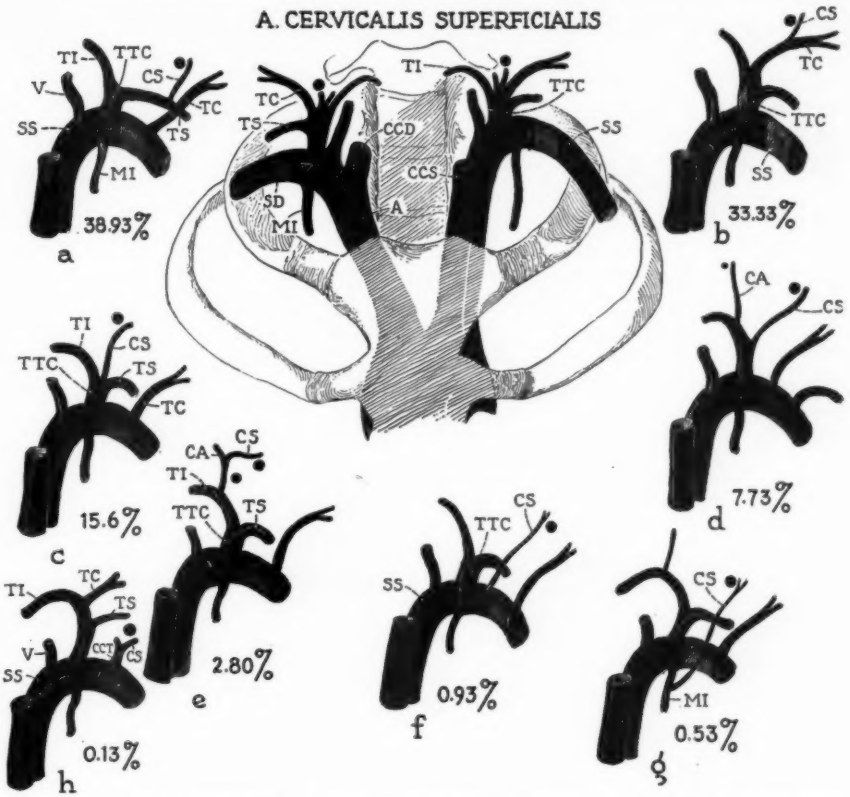



FIG. 7. Superficial cervical artery. a, Branch of transverse scapular artery; 292 of 750 sides, 38.93 per cent; 139 right, 153 left. b, Branch of transverse cervical artery; 250 of 750 sides, 33.33 per cent; 125 right, 125 left. c, Direct branch of thyrocervical trunk (Figs. 7 key, bilateral, and 7c); 117 of 750 extremities, 15.6 per cent; 68 right, 49 left. d, Branch of the inferior thyroid artery; 58 of 750 extremities, 7.73 per cent; 27 right, 31 left. e, As common trunk with ascending cervical artery; 21 of 750 sides, 2.80 per cent; 6 right, 15 left. In 31 additional cases, the small ascending cervical arose as a branch of the superficial cervical artery, derived in turn from some other source. f, Direct branch from first portion of subclavian artery; 7 of 750 extremities, 0.93 per cent; 7 right, 0 left. g, Branch of internal mammary artery; 4 of 750 sides, 0.53 per cent; 1 right, 3 left. h, From common trunk with the deep cervical artery or costocervical trunk; 1 of 750 specimens, 0.13 per cent, left side.

### THE ASCENDING CERVICAL ARTERY

The ascending cervical artery is usually described as a small branch arising from the inferior thyroid artery as that vessel crosses behind the carotid sheath, or from the thyrocervical trunk. It then courses almost vertically upward, lying parallel and medial to the phrenic nerve between the anterior scalene and longus capitis muscles and supplying twigs to the deep cervical musculature. It forms multiple anastomotic connections with the vertebral, ascending pharyngeal, deep cervical, and occipital arteries.

Thus it becomes evident that the ascending cervical artery has a fairly constant source of origin, occurring as a branch of the inferior thyroid artery in approximately 70 per cent of all cases. However, in the remaining 30 per cent, the site of origin is almost equally divided among the thyrocervical trunk proper, the transverse cervical, transverse scapular, and superficial cervical

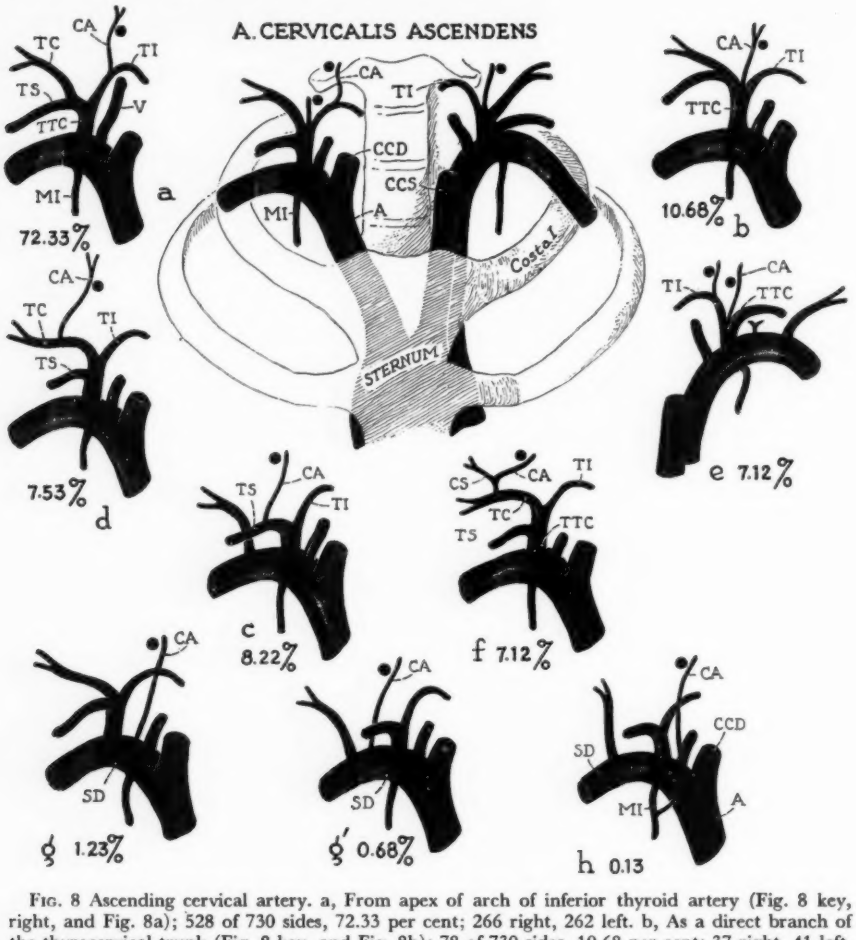



FIG. 8 Ascending cervical artery. a, From apex of arch of inferior thyroid artery (Fig. 8 key, right, and Fig. 8a); 528 of 730 sides, 72.33 per cent; 266 right, 262 left. b, As a direct branch of the thyrocervical trunk (Fig. 8 key, and Fig. 8b); 78 of 730 sides, 10.68 per cent; 37 right, 41 left. c, Branch of the transverse scapular artery; 60 of 730 extremities, 8.22 per cent; 29 right, 31 left. d, Branch of the transverse cervical artery; 55 of 730 extremities, 7.53 per cent; 32 right, 23 left. e, Dual ascending cervical arteries; 52 of 730 sides, 7.12 per cent; 29 right, 23 left. (In 16 instances, both vessels arose from the inferior thyroid artery; in 28 cases, 1 arose from the inferior thyroid, 1 from the thyrocervical trunk or one of its branches. In 8 instances, both vessels arose from the thyrocervical trunk, or one of its branches other than the inferior thyroid artery.) f, Branch of the superficial cervical artery; 52 of 730 sides, 7.12 per cent; 27 right, 25 left. g and g′, Direct branch of subclavian artery; 14 of 730 extremities, 1.91 per cent; 11 right, 3 left. From the first portion of subclavian, 9 sides, 1.23 per cent; from the second portion of the subclavian, 5 sides, 0.68 per cent. h, As a branch of the internal mammary artery; 1 of 730 sides, 0.13 per cent; 1 left side.

arteries. Origin may infrequently occur as a direct branch of the first or second portions of the subclavian artery. Multiplicity of this vessel is extremely common, as many as 4 separate vessels being encountered on rare occasions.

These results on the ascending cervical artery agree in most essentials with those obtained by both Yazuta and by Dubreuil-Chambardel. Their higher incidence of origin from the thyrocervical trunk (25.5 per cent) can best be explained by their

failure to subdivide the thyrocervical trunk into its component branches. Our present totals range above 100 per cent because of the marked frequency of duplication as compared to absence of the ascending cervical artery.

The ascending cervical artery is commonly a very slender and insignificant arterial twig, and of little surgical importance. However, because of its location (parallel and medial to the phrenic nerve) and its course (vertically upward between the anterior scalene and longus capitis muscles), it might readily be mistaken for the main phrenic or an accessory phrenic nerve. Certainly crushing of this vessel would not affect the diaphragm and might, instead, result in troublesome bleeding.

### THE INTERNAL MAMMARY ARTERY

The internal mammary artery usually takes origin from the lower border of the first portion of the subclavian artery, opposite the thyrocervical trunk and near the medial edge of the anterior scalene muscle. It descends in an inward and slightly forward direction to enter the thorax behind the cartilage of the first rib. It then passes downward behind the cartilages of the succeeding ribs to the sixth interspace, lying approximately 1.2 to 1.5 centimeters lateral to the sternum where it divides into its terminal branches, the superior epigastric and musculophrenic. The cervical portion of this vessel is covered by the sternocleidomastoid muscle and the subclavian and internal jugular veins, and is crossed obliquely by the phrenic nerve. It lies upon the pleural cupola and courses around the upper portion of the innominate vein. The cervical portion of the internal mammary artery is regularly described as having no branches; however, it frequently gives rise to one or more of the thyrocervical or subclavian branches. The thoracic portion of this vessel (not studied in the current series) lies behind the cartilages of the upper 6 ribs and gives off several important branches: the pericardiacophrenic, anterior mediastinal, thymic, bronchial, pericardiac, sternal, anterior intercostal, anterior perforating, lateral costal, superior epigastric and musculophrenic arteries. Important anastomotic channels are established, through the terminal branches of the internal mammary artery, with the inferior epigastric and deep circumflex iliac branches of the external iliac artery. In addition, through its anterior intercostal branches, it forms important anastomoses with the intercostal branches of the thoracic aorta.

Duplication of the internal mammary artery was not encountered in the present series; however, absence of this vessel was noted twice (.28 per cent), once on either side.

In the past, the internal mammary artery, its accompanying veins, lymph nodes, and lymphatic channels have been of little surgical interest or importance. However, the recent works of Handley, Urban, and Wangensteen seem to indicate that these structures will assume a much more important role.[1] If metastases from carcinoma of the breast into the internal mammary chain of lymph nodes occur as commonly as Handley's studies would indicate, then, in order to improve our surgical results, excision of these structures becomes imperative. This step would increase the magnitude of radical mastectomy; however, if a commensurate increase in cures results, the procedure should be utilized.

### THE COSTOCERVICAL TRUNK

The costocervical trunk is a short arterial trunk which usually arises from the posterior surface of the second portion of the subclavian artery on the right and the terminal part of the first portion of that vessel on the left side. At first it passes superomedially,

[1] As this article is being prepared for publication, report of an even more important surgical use of the internal mammary arteries has been announced by Robert P. Glover of Philadelphia. Glover's procedure of severing and tying off both internal mammary arteries and branches other than the pericardiacophrenic arteries distal to this latter vessel, thus shunting the full arterial supply of the internal mammary arteries into the pericardiacophrenic branches, has brought relief to a small series of patients suffering from coronary arterial insufficiency. Further clinical and anatomic studies are necessary.

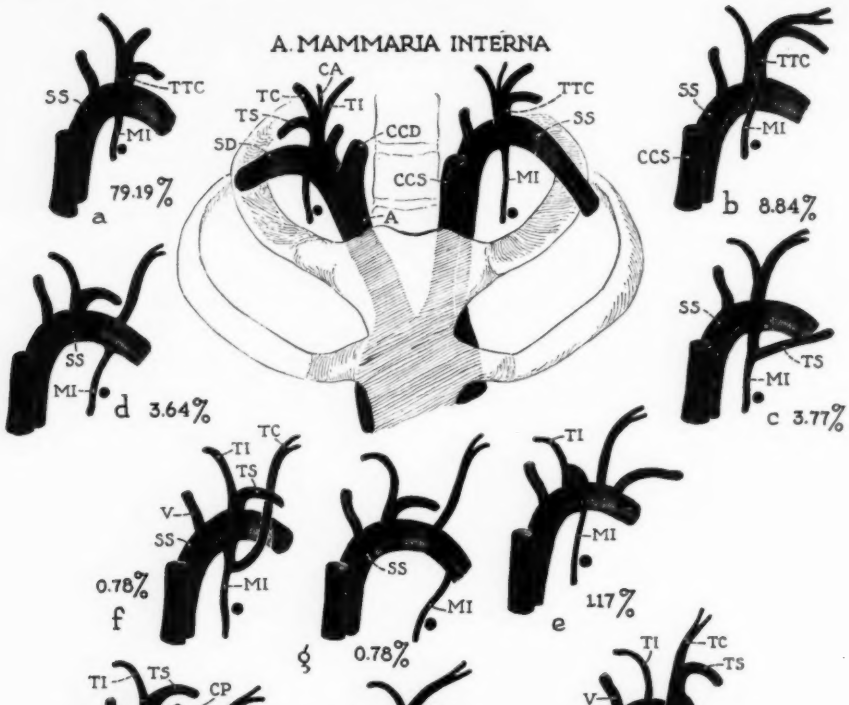



FIG. 9. Internal mammary artery. a, Branch of first portion of subclavian artery (Fig. 9 key, bilateral, Fig. 9a); 609 of 769 sides, 79.19 per cent; 324 right, 285 left. b, From common stem with thyrocervical trunk (Fig. 9b); 68 of 769 extremities, 8.84 per cent; 11 right, 57 left. c, From common trunk with transverse scapular artery; 29 of 769 extremities, 3.77 per cent; 9 right, 20 left. d, Direct branch of second portion of subclavian artery; 28 of 769 extremities, 3.64 per cent; 6 right, 22 left. e, From common trunk with inferior thyroid artery; 9 of 769 sides, 1.17 per cent; 5 right, 4 left. f, From common trunk with transverse cervical artery; 6 of 769 sides, 0.78 per cent; 2 right, 4 left. g, Direct branch from the third portion of the subclavian artery; 6 of 769 sides, 0.78 per cent; 4 right, 2 left. h, From common trunk with superior intercostal artery; 6 of 769 sides, 0.78 per cent; 4 right, 2 left. i, Direct branch from axillary artery; 4 of 769 extremities, 0.52 per cent; 2 right, 2 left. j, Internal mammary, transverse cervical, and transverse scapular arteries, all from common trunk; 2 of 769 extremities, 0.28 per cent; 1 right, 1 left.

then curves posteroinferiorly; after giving rise to its deep cervical arterial branch, it continues as the superior intercostal artery. This latter vessel courses over the dome of the pleura, anterior to the surface of the necks of the first two ribs, opposite which it usually gives off branches to the first 2 intercostal spaces.

The deep cervical artery courses backward between the seventh and eighth cervical nerves toward the body of the seventh cervical vertebra; it then turns upward in the

groove between the transverse and spinous processes of the cervical vertebrae where it lies between the semispinalis colli and capitis muscles. The artery forms anastomotic connections with the descending branch of the occipital artery, as well as with the vertebral and ascending cervical arteries. It furnishes numerous branches to the adjacent musculature and also gives off a spinal branch that enters the vertebral canal in company with the eighth cervical nerve.

The superior intercostal artery passes into the thorax in front of the neck of the first rib. In some cases it may terminate in the first intercostal space by forming the first intercostal artery. It forms anastomotic communications with the highest aortic intercostal artery and may also connect with an anterior aberrant branch of the thoracic aorta.

Since the presence or absence of the costocervical trunk was not recorded in all of the sketches prepared, only completely reliable records have been used. Such data were available in a total of 611 extremities: 310 times on the right side and 301 on the left.

The costocervical trunk and its branches, the deep cervical and superior intercostal arteries, are not of great surgical importance. These are small vessels with rich anastomotic connections and, therefore, of some importance solely as collateral channels when the vertebral, subclavian arteries and their branches require ligation or excision. The costocervical trunk and its superior intercostal branch may also be hypertrophied when coarctation of the aorta occurs. This trunk and its branches can usually be ligated with impunity. Their real surgical importance is due to their inaccessibility; arising from the posterior or deep surface of the subclavian, they bifurcate almost immediately, the branches then penetrating the deep muscular and fascial structures of the neck and thorax. If torn or severed during mobilization of their subclavian source, they could cause troublesome hemorrhage, with the accompanying danger of injury to more vital adjacent structures.

### THE SUPERIOR THYROID ARTERIES

The superior thyroid artery is usually described as the first or second branch of the external carotid artery, and as then coursing medially and downward, to end by division into its terminal branches at the upper pole of the thyroid gland. Throughout its course it gives off several small arterial twigs: the hyoid, sternocleidomastoid, superior laryngeal, cricothyroid, and muscular arteries. The hyoid branch is usually quite small, supplying the thyrohyoid and sternocleidomastoid; it also supplies small branches to the platysma, suprahyoid and infrahyoid muscles. The superior laryngeal branch is a small vessel (accompanying the superior laryngeal nerve) that supplies the intrinsic musculature and mucosa of the larynx. The cricothyroid is usually the largest branch of the superior thyroid artery. It arises near the lower edge of the thyroid cartilage and courses across the cricothyroid membrane, eventually to supply the isthmus and pyramidal lobe of the thyroid gland. The muscular branches are usually small in caliber and supply the constrictor muscles of the pharynx.

In the present series of 180 sides (93 on the left and 87 on the right), studies were made to determine the exact site of origin of the thyroid artery, and measurements were made of its length. It came as a distinct surprise to find that in 81 (45 per cent) of the sides examined, the superior thyroid artery arose, not as a branch of the external carotid artery, but directly from the carotid bulb just below the point of bifurcation of the common carotid artery.

In 98 of the sides (54.44 per cent, 56 on the right, 42 on the left), the superior thyroid artery arose as the first branch of the external carotid artery. In a single specimen, on the right side, the superior thyroid artery arose from a common trunk with the external maxillary and lingual arteries, as the second branch of the external carotid artery.

The length of the superior thyroid artery, from its carotid bulb or external carotid origin to the point of bifurcation into its

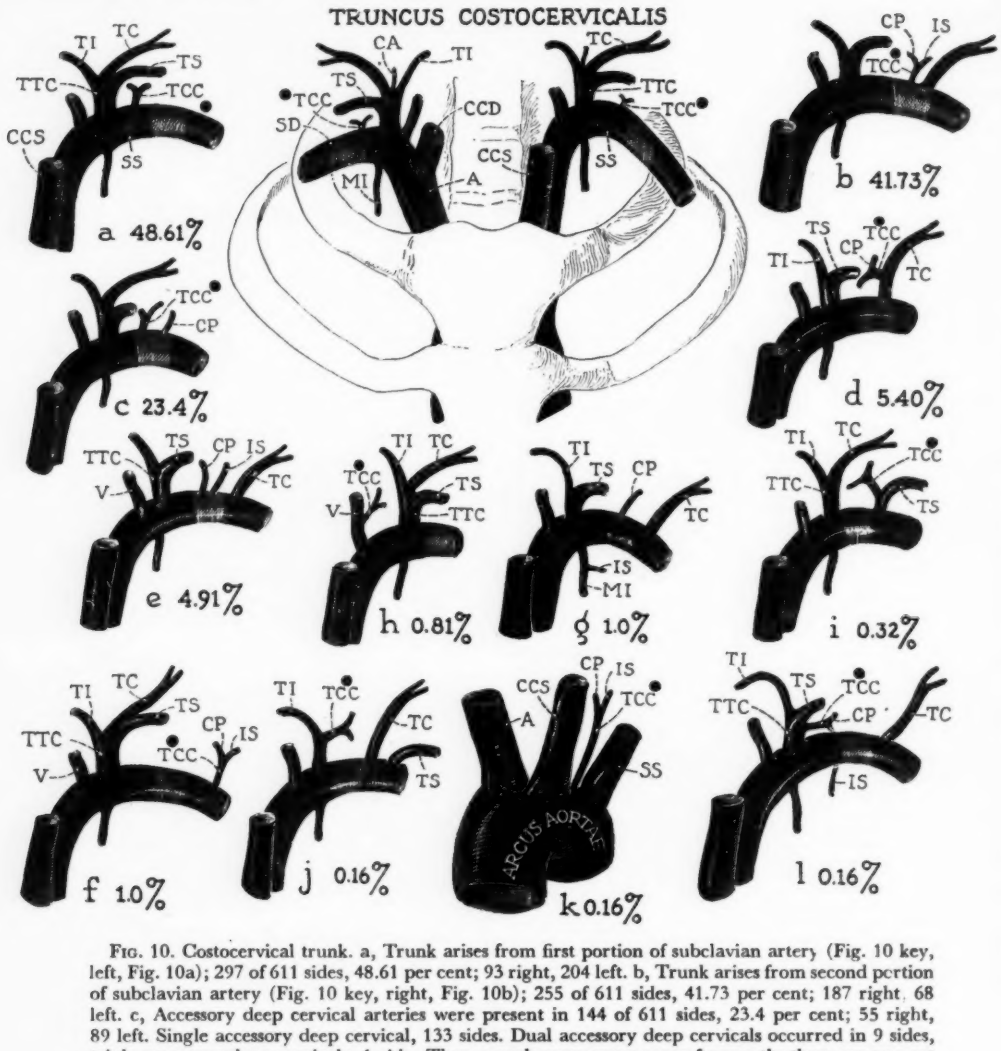



FIG. 10. Costocervical trunk. a, Trunk arises from first portion of subclavian artery (Fig. 10 key, left, Fig. 10a); 297 of 611 sides, 48.61 per cent; 93 right, 204 left. b, Trunk arises from second portion of subclavian artery (Fig. 10 key, right, Fig. 10b); 255 of 611 sides, 41.73 per cent; 187 right, 68 left. c, Accessory deep cervical arteries were present in 144 of 611 sides, 23.4 per cent; 55 right, 89 left. Single accessory deep cervical, 133 sides. Dual accessory deep cervicals occurred in 9 sides, triple accessory deep cervicals, 1 side. These vessels may occur more frequently than our present study might indicate, owing to loss in dissection. d, Costocervical trunk proper, or its deep cervical branch, arose as a branch from the transverse cervical artery; 33 of 611 extremities, 5.40 per cent; 11 right, 22 left. Costocervical trunk proper, 13 of 611 sides, 2.12 per cent; 5 right, 8 left. e, Absent costocervical trunk; 30 of 611 extremities, 4.91 per cent; 18 right, 12 left. Both branches from subclavian artery, 24 sides. Deep cervical from subclavian, superior intercostal from internal mammary, 6 sides. f, Trunk arises from third portion of subclavian artery; 6 of 611 extremities; 1.0 per cent; 4 right, 2 left. g, Superior intercostal artery arises as direct branch of internal mammary artery; 6 of 611 extremities, 1.0 per cent; 4 right, 2 left. h, Trunk arises as branch of vertebral artery; 5 of 611 sides, 0.81 per cent; 2 right, 3 left. i, Trunk arises as branch of transverse scapular artery; 2 of 611 sides, 0.32 per cent; both left. j, Trunk arises as branch of inferior thyroid artery; 1 of 611 sides, 0.16 per cent; right side. k, Costocervical trunk arising as direct branch of aortic arch between left common carotid and subclavian arteries; 1 of 611 sides. 0.16 per cent; left side. l, Trunk arises as branch of thyrocervical trunk; 1 of 611 sides, 0.16 per cent; left side.

terminal glandular branches, was measured in 215 of the sides examined (107 on the right, 108 on the left). The average length of the superior thyroid artery from its origin to its first glandular branch (which frequently was the cricothyroid) was 3.74 centimeters on the right side and 3.92 centimeters on the left. The longest superior thyroid arterial trunk measured was 6.5 centimeters, whereas the shortest encountered was but .8 centimeter, both of these extremes being found on the right side.

The surgical importance of the superior thyroid artery is obvious to anyone performing surgery upon the thyroid gland or the cervical regions. However, lack of knowledge about the frequency of its origin from the carotid bulb can best be demonstrated by the illustrations in 2 recent articles on carotid body tumors by Lahey and Warren (22), and by Warren (35), in which a superior thyroid artery from the carotid bulb is termed anomalous. Certainly such a vessel represents a common variation, occurring as it does in 45 per cent of the cases studied in the present series.

In performing a thyroidectomy, the superior polar vessels are usually dealt with (on their respective sides) immediately after the lobe has been adequately exposed, and following mobilization with severance of the middle thyroid vein. The superior pole can then be exposed in its entirety by downward traction on the lobe, either by grasping the lobe between the thumb and index finger, or by the application of a pair of toothed forceps or small towel clips. Adenomatous tissue may project well above and posterior to the junction of the superior pole vessels and the gland. It should be carefully searched for, and delivered with the gland if possible. The senior author has used a technique popularized by Frederick Coller, in which the superior thyroid vessels are secured just above their joining of the upper pole by means of blunt, hemostat dissection, carried out from the midline laterally in the avascular cricothyroid space. Using this approach, the superior pole vessels can usually be identified, cleaned of surrounding fibroadipose tissue, clamped, severed, and doubly ligated before resection of the lobe is attempted. The point at which the superior thyroid vessels are dissected is usually well below the level of the superior laryngeal nerve and vessels. However, injury to these structures is to be avoided. Nordland has given accurate and detailed descriptions of the position and relationships of this nerve and its branches.

Finally, in 133 of the body sides (88 on the right and 45 on the left), measurements were taken of the length of the common carotid arteries. The right common carotid artery, due to its innominate origin, was much shorter than the left. The average length was 9.8 centimeters, with a maximum of 12.5 centimeters and a minimum of 6.7 centimeters. The average length of the left common carotid artery was 12.53 centimeters, the longest vessel measuring 16 centimeters, whereas the shortest vessel was but 9.5 centimeters in length.

## SUMMARY

On the basis of an anatomic study of 400 dissection room specimens, the arterial patterns and types of variation of the subclavian arteries and their branches have been described and figured.

The relationships of the subclavian arterial arch to the apex of the pulmonary pleura, to the interscalene triangle and its contents have been reviewed in detail.

The sites of entrance of the vertebral arteries into the foramina of the transverse processes of the cervical vertebrae, and their number and percentages of occurrence have been recorded.

The inferior thyroid arterial trunks were classified on the basis of origin; additionally, data on the length of this vessel and its relations to the recurrent laryngeal nerves have been presented. In a limited number of specimens, detailed studies were made of the arterial branches to the cervical and upper thoracic portions of the esophagus and trachea.

Variations in source and length of the superior thyroid arteries, their sites of origin, and length have been considered, as well as differences in length of the common carotid arteries.

The clinical significance of the observations on the subclavian artery, and on its major branches, has been discussed in those instances in which less critical knowledge of anatomy would lead to hazard in surgery of the neck and in the upper thorax.

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# PULMONIC STENOSIS WITH INTACT INTERVENTRICULAR SEPTUM

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PULMONIC STENOSIS with intact interventricular septum furnishes a challenge to the surgeon. The obstruction in most cases is valvular and, unlike the indurated tissues of rheumatic valvular stenosis, the involved pulmonic valve tends to remain pliable for many years. It is in this group especially that consistently excellent results should be attainable. During the past 7 years this clinic has operated on valvular pulmonic stenosis with intact interventricular septum by a modified Brock transventricular valvotomy. A smaller group with intact septum has required infundibular resection. Hemodynamically the results have not been perfect, however, there have not been any operative deaths.

The prospect of exact valvular reconstruction under direct vision captivates the minds of all investigators interested in this field, and one must be cautiously objective in evaluating the amount of good and harm done to the patients by any procedure. With this expectant but watchful philosophy in mind, 46 cases of pulmonic valvular and/or infundibular stenosis with intact interventricular septum are presented in this article.

*Material and Methods.* The patients ranged in age from 2 to 42 years with an average age at operation of 13 years. There were 19 males and 27 females; 2 were negroes and the rest white. Thirty-four patients had transventricular valvotomy only, 6 had infundibular resection by a previously described technique using a pituitary rongeur (3), and 6 had both valvotomy and infundibular resection. The diagnosis in all but 3 cases was ascertained by catheterization of the right side of the heart although clinical signs and other laboratory studies were of importance.

Valvotomy was performed through an anterolateral incision of the fourth left intercostal space. A rectangular flap of pericardium was raised medially to expose the outflow tract of the right ventricle. The heart was inspected, palpated for thrills, and operative pressure studies were taken. Stay sutures were then placed in the outflow tract and an expandable dilator inserted into the valve through the myocardium to measure the orifice size. A valvulotome was then advanced into the outflow tract. In the earlier cases Brock knives were employed but presently a Potts-Ricker expanding valvulotome with maximum cutting width of 22 millimeters is used (Fig. 1). Subsequent dilatation of the valve was then carried out with a mechanical dilator (usually the Brock aortic dilator). Pressures were again taken in the right ventricle and pulmonary artery and, if necessary, further manipulation was carried out. The ventricular outflow tract was also probed or palpated to determine the presence of infundibular obstruction. When found the crista supraventricularis was resected with a pituitary-type rongeur. At the termination of the procedure the myocardial wound was closed with 3 or 4 interrupted stitches. The operative field was flushed with warm saline, the pericardium partially approximated, and the chest wall was then closed in the routine manner.

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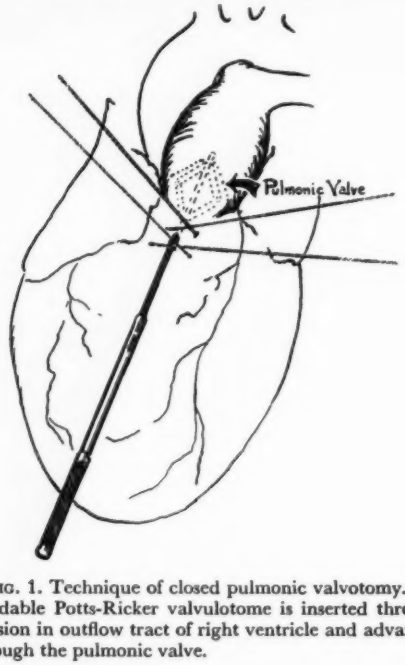


FIG. 1. Technique of closed pulmonic valvotomy. Expandable Potts-Ricker valvulotome is inserted through incision in outflow tract of right ventricle and advanced through the pulmonic valve.

*Clinical status.* Interestingly enough, although symptomatology rarely was the determining factor for operation, only 5 patients in this study were asymptomatic prior to surgery. Fatigue and dyspnea were noted by more than half of the patients. Other symptoms in diminishing frequency included frequent upper respiratory infections, chest pain, restricted activity, syncope, and palpitation. Paroxysmal nocturnal dyspnea, orthopnea, and dizziness were rare symptoms.

All the patients had a systolic murmur at the pulmonic area, and 28 of them had an associated thrill. The pulmonic second sound was usually diminished or absent. Twenty patients had a history of cyanosis but squatting occurred in only 4 and clubbing in 3. Enlargement of the liver was present in 3 individuals, and 1 had peripheral edema. There was occasionally limitation of growth but only 2 children were definitely underdeveloped.

*Cardiograms and roentgenograms.* Of the 44 patients whose electrocardiograms were available for review, all were in sinus rhythm. There were 3 cases of incomplete right bundle branch block, but there was evidence of moderate to marked right ventricular preponderance in 38 (Fig. 2). Right atrial enlargement was often suggested by the presence of high peaked P waves in limb lead II.

The x-ray studies in this group varied from normal to striking, and no particular correlation with symptomatology or pressure gradient could be demonstrated. Three patients had normal radiographic studies without evidence of right ventricular enlargement, change in the pulmonary artery segment, or diminished lung vascularity. Three others showed smaller than normal pulmonary arteries. About one-half of the patients (21) had definite enlargement of the main pulmonary artery (Fig. 3), and occasionally this appeared aneurysmal. Right ventricular enlargement was the most common variation (27 cases) manifested by elevation of the apex and prominence of this chamber on the lateral as well as the right anterior oblique views.

*Cardiac catheterization.* Although statistically the majority of patients with significant pulmonic stenosis will have clinical, electrocardiographic, and radiologic indications of their disease, the decision for surgery in any individual case usually rests on the results of cardiac catheterization (Fig. 4). It has, in general, been believed that, except in patients over 50 years of age or those with specific contraindications, surgery should be performed whenever there is a "resting" peak systolic gradient from the right ventricle to the pulmonary artery of over 70 to 75 millimeters of mercury. The average gradient for this series of patients was 102 millimeters of mercury preoperatively although gradients as high as 220 millimeters of mercury were recorded. The average peak systolic pressure in the right ventricle was 113 millimeters of mercury, ranging to 240 millimeters of mercury in 1 case. In spite of the frequent admonition that pressures taken on the operating table are of little value be-

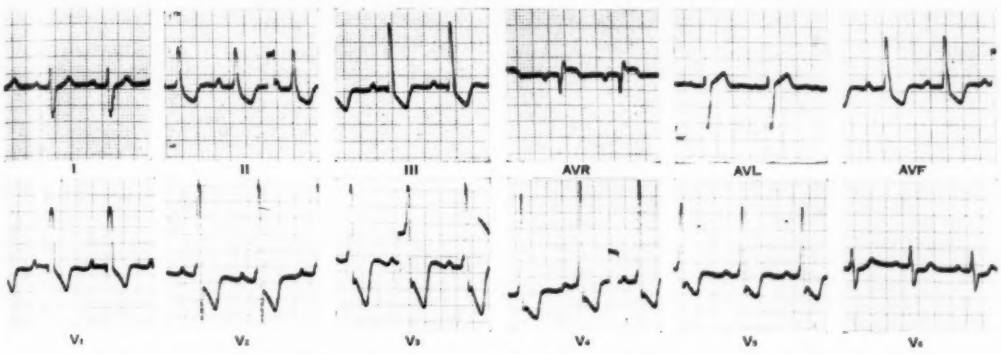


FIG. 2. Typical electrocardiogram of patient with pulmonic stenosis showing marked right ventricular preponderance.

cause of anesthesia, diminished cardiac output, and other ill-defined variables, there was surprisingly little difference from the preoperative observations. The average peak systolic gradient across the pulmonic valve at operation prior to valvotomy was 97 millimeters of mercury or only 5 millimeters less than obtained during preoperative study. The highest gradient recorded at the time of surgery was 175 millimeters of mercury with a maximum right ventricular systolic pressure of 200 millimeters of mercury.

## RESULTS

When weighing the results of an operation such as this, consideration must be given to the operative mortality, subsequent clinical status, and hemodynamic improvement. Theoretically, complete ablation of the pressure differential across the valve is desirable, and yet many people who live normal lives with demonstrable pressure gradients are brought to the cardiologist's attention only because of a murmur. Certainly this point must be seriously regarded whenever there is operative risk to the chosen procedure.

*Mortality.* There have been no operative deaths in this series. One child with infundibular and valvular stenosis died from cardiac failure 8 months after surgery was performed.

*Clinical status.* As noted earlier, only 5 patients in this study were asymptomatic prior to surgery, the remainder most commonly having shortness of breath and easy fatigability. The 5 asymptomatic patients have remained free of symptoms since operation. Twenty-six patients who manifested symptoms before surgery have become completely free of them since. Six patients have shown improvement but continue to have occasional difficulty with increased activity, and there are 5 who have experienced no symptomatic change. Of the remaining patients, 3 have been operated upon too recently for evaluation, and 1 has, as previously mentioned, died 8 months after valvotomy with infundibular resection.

For simplicity the clinical results have been tabulated as follows: excellent, 25; good, 12; fair, 3; poor, 2 and deceased, 1 (These latter 3 patients had both valvotomy and infundibular resection); recent operation, 3.

The electrocardiogram has shown improvement of the right ventricular hypertrophy pattern in 7 of 24 with serial studies available (Fig. 5). The others have not shown regression to date. The roentgenograms in 8 of the 26 patients of whom comparative films were made have reverted to "normal," but there has been no change in 12 others.

*Hemodynamic results.* Pressure studies at surgery following valvotomy have revealed narrowing of the pulmonic valve gradient

FIG. 3. X-ray appearance of poststenotic dilatation of the main pulmonary artery found in about one-half of the patients in this series.

by concomitant lowering of the right ventricular pressure and elevation of the pressure in the pulmonary artery. Preoperative catheterization had shown an average systolic peak gradient of 102 millimeters of mercury and an essentially similar figure of 97 millimeters of mercury was recorded at surgery before valvotomy. Following completion of valvular surgery the average gradient dropped to 44 millimeters of mercury on the operating table. The gradient in 1 patient, however, remained 175 millimeters of mercury in spite of repeated manipulations. The average peak systolic right ventricular pressure for the series dropped from 125 to 82 millimeters of mercury.

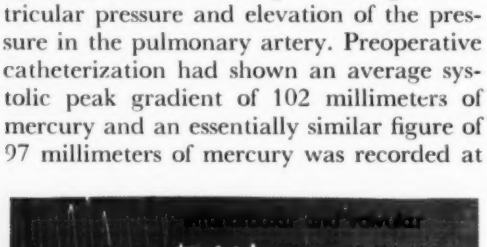


FIG. 4. Pressure tracings at cardiac catheterization illustrating peak systolic pressure differentials between right ventricle, infundibulum, and pulmonary artery in 1 case and between right ventricle and pulmonary artery in another patient with pure valvular stenosis.

Follow-up cardiac catheterization studies have been obtained on 21 patients, an average of 3½ years after surgery. There was evidence of further diminution of the systolic pressure in the right ventricle, the average being 62 millimeters of mercury and the highest 125 millimeters of mercury. The average peak systolic gradient dropped to 33 millimeters of mercury (28 mm. Hg for the 17 patients with pure valvular stenosis without infundibular involvement). It was somewhat disheartening to find, however, that 4 patients with pure valvular stenosis still had gradients from 50 to 82 millimeters of mercury (Table I).

## CASE REPORT

The patient with a residual gradient of 82 millimeters of mercury is presented in some detail. This 42 year old, white female was a "blue baby." Her activities were restricted during childhood but she occasionally noted shortness of breath on vigorous exercise. No history of rheumatic fever could be obtained. She remembered that at age 13 she took digitalis for a short while and again during a pregnancy at age 21. She was confined to bed throughout this pregnancy. Subsequently, she was troubled by shortness of breath, markedly limited activity, dizziness, weakness, syncope, and blueness of her fingers and toes. She liked to dance but was not able to last more than one-half a dance.

The electrocardiogram showed sinus arrhythmia with a rate of 63. The PR interval measured 0.20 second and the QRS, 0.10 second. There was right axis deviation with inversion of the T waves and ST depression

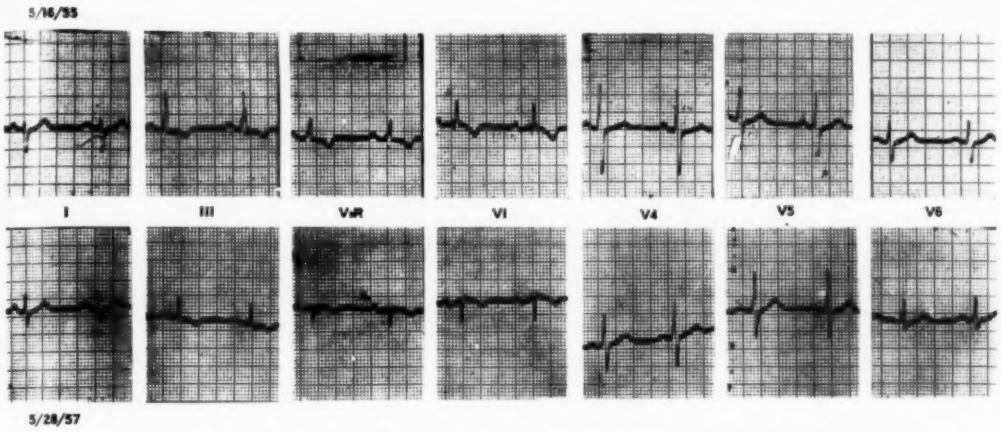


FIG. 5. Electrocardiograms showing preoperative right ventricular hypertrophy and subsequent postoperative changes toward normal following pulmonic valvotomy.

in leads II, III, AVF, and all precordial leads. Roentgenograms revealed 2 to 3 plus enlargement of the pulmonary artery with small branch vessels. The right ventricle was enlarged (2 plus) and the other chambers were normal. Laboratory studies were completely normal with no evidence of polycythemia.

Preoperative cardiac catheterization revealed:

| | *$O_2$ content, vol. per cent* | *Pressures, mm. Hg* |
|---|---|---|
| Superior vena cava | 10.00 | |
| Right atrium | 11.63 | 16/7 |
| Right ventricle | 11.32 | 240/16 |
| Pulmonary artery | 11.38 | 20/14 |
| Femoral artery | 20.81 (93.9%) | 124/84 |
| Pulmonary blood flow | 2.092 l./min. | |
| Systemic blood flow | 2.130 l./min. | |

Pulmonary valvotomy was performed in March 1957, and although the anatomic orifice was opened to the full extent of the dilator, the systolic thrill lessened and the tension in the pulmonary artery increased, the pressure gradient remained essentially unchanged at the level of 175 millimeters of mercury.

The patient was restudied 1 year later. Symptomatically her result was excellent for with the exception of occasional lightheadedness and blueness of her toes she felt normal. There was no further shortness of breath or fatigue, and she stated enthusiastically that she could and often did dance for hours. The electrocardiogram showed improvement but the radiologic studies were essentially the same as before surgery. The following results were obtained at cardiac catheterization 1 year after surgery was completed:

| | *$O_2$ content, vol. per cent* | *Pressures, mm. Hg* |
|---|---|---|
| Superior vena cava | 9.50 | |
| Right atrium | 11.95 | 18/6 |
| Right ventricle | 11.23 | 110/0 |
| Pulmonary artery | 11.16 | 28/13 |
| Brachial artery | 16.74 (90%) | 160/88 |
| Pulmonary blood flow | 3.2 l./min. | |
| Systemic blood flow | 3.2 l./min. | |

## DISCUSSION

The present era of cardiac surgery has created thoughtful conflicts in the minds of most investigators. We are coming to the point of deciding whether all cardiac surgery should be done by open-heart techniques relegating the closed methods to the horse-and-buggy era of cardiac surgery, or whether certain intracardiac procedures will continue to be best done without the complexity of a direct visual approach. This problem is illustrated by the management of pulmonic stenosis. Blount has reported physiologic studies in 25 of 38 patients operated upon under direct vision with hypo-

TABLE I.—HEMODYNAMIC RESULTS OF PATIENTS RECATHETERIZED AFTER SURGERY

| Patient | Preoperative | | | Postoperative recatheterization | | | |
|---|---|---|---|---|---|---|---|
| | RV | PA | Gradient | RV | PA | Gradient | Interval from surgery to catheterization |
| 1. E.C. | 112/12 | Not entered | | 70/0 | Not entered | | 4 yrs. 2 mos. |
| 2. G.C. | 88/2 | Not entered | | 76/8 | 23/13 | 53 | 6 yrs. 2 mos. |
| 3. N.S. | 90/10 | Not entered | | 95/5 | 20/10 | 75 | 5 yrs. 3 mos. |
| 4. R.H. | 200/18 | 15/10 | 185 | 53/8 | 27/11 | 26 | 9 mos. |
| 5. M.L.* | 75/0 | 26/15 | 49 | 50/0 | 25/8 | 25 | 1 yr. 2 mos. |
| 6. A.D. | 60/5 | 22/8 | 38 | 48/6 | 26/10 | 22 | 7 yrs. 2 mos. |
| 7. T.B.* | 134/0 | Not entered | | 80/0 | 15/8 | 65 | 1 yr. 1 mo. |
| 8. C.P. | 170/8 | 25/10 | 145 | 45/9 | 36/15 | 9 | 3 yrs. 10 mos. |
| 9. R.B. | 120/0 | 10/4 | 110 | 50/10 | 32/14 | 18 | 4 yrs. |
| 10. G.H.* | 100/5 | Not entered | | 100/5 | 12/8 | 88 | 4 yrs. 10 mos. |
| 11. D.A. | 110/0 | 20/10 | 90 | 40/10 | 28/10 | 12 | 3 yrs. 5 mos. |
| 12. E.B. | 90/45 | Not entered | | 38/10 | 30/12 | 8 | 3 yrs. 5 mos. |
| 13. P.L. | 110/0 | 20/0 | 90 | 42/16 | 32/18 | 10 | 2 yrs. 11 mos. |
| 14. K.N. | 120/0 | 12/8 | 108 | 40/5 | 30/10 | 10 | 2 yrs. 8 mos. |
| 15. D.T. | 168/8 | 13/2 | 155 | 45/8 | 25/12 | 20 | 2 yrs. 4 mos. |
| 16. B.G. | 200/0 | 28/10 | 172 | 40/5 | 25/10 | 15 | 2 yrs. |
| 17. K.W. | 144/0 | 14/2 | 130 | 64/4 | 40/8 | 24 | 1 yr. 7 mos. |
| 18. K.M. | 76/0 | 10/6 | 66 | 55/10 | 30/13 | 25 | 1 yr. 10 mos. |
| 19. D.F. | 105/0 | 15/10 | 90 | 125/12 | 56/16 | 69 | 1 yr. 9 mos. |
| 20. W.K. | 124/0 | 7/2 | 117 | 42/10 | 28/13 | 14 | 1 yr. |
| 21. T.S. | 240/16 | 20/14 | 220 | 110/10 | 28/13 | 82 | 1 yr. |

*Infundibular.

thermia. There were 2 operative deaths. The hemodynamic results surpass those reported for the closed techniques with reduction of the average gradient from 115 to 16 millimeters of mercury. Surgical correction of 10 cases at the Mayo Clinic by means of extracorporeal circulation and open cardiotomy resulted in a striking reduction of the reported gradients with no operative mortality (4). There was 1 death 3 months postoperatively following saddle embolus of the aorta. It is hard to escape the conclusion that perhaps the persistently elevated gradients after closed valvotomy are the result of an incomplete operation rather than the gradual adjustment of the right ventricular outflow tract to new dynamics.

Our own hemodynamic results with closed valvotomy with or without infundibular resection have not been as impressive, and yet the resultant average gradients of 33 millimeters of mercury for the group as a whole and 28 millimeters of mercury for the pure valvular stenotics place most of these patients into a category where one would not consider operating on them. Moreover, there have been no operative deaths, and the clinical outcome has been good or excellent in 86 per cent. Obviously in such a rapidly progressing field as cardiac surgery, there is little room for dogmatic statements about specific surgical methods, but impressions based on statistical review of cases help us to incorporate new ideas without necessarily abandoning techniques that have proved their value. The possibility of overlooking an interventricular septal defect and the sometimes uncertain results with infundibular resection have led us to elect direct visual methods for the correction of infundibular stenosis in any combination. We are not yet ready, however, to disown the simple, safe, Brock-type valvotomy as the treatment of choice for pure valvular pulmonic stenosis.

## SUMMARY AND CONCLUSIONS

1. Forty-six cases of pulmonic stenosis with intact interventricular septum are reviewed. These patients were treated by closed valvotomy and/or infundibular resection.

2. There were no operative deaths. One patient with infundibular and valvular stenosis died 8 months after operation was performed.

3. The average peak systolic pressure gradient was 102 millimeters of mercury

preoperatively. Operative pressure studies showed a drop from 97 to 44 millimeters of mercury for the series. Twenty-one patients have been recatheterized, an average of 3½ years after surgery was performed, and the gradient for the series has further decreased to 33 millimeters of mercury. The mean postoperative gradient for the patients with valvular stenosis alone was 28 millimeters of mercury.

4. Clinical results were good to excellent in 86 per cent.

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# MALIGNANT LYMPHOMAS OF THE GASTROINTESTINAL TRACT

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MALIGNANT LYMPHOMAS localized to the gastrointestinal tract are not common, but these tumors may be encountered occasionally in the average practice of surgery. Despite the large literature on this subject, the number of reported long-term follow-up examinations is sufficiently small to warrant a documentation of the experience at Duke Hospital. A complete review of the literature is not attempted, but the recent and more comprehensive reviews have been used for comparison. This article is presented to review the experience with malignant lymphomas of the gastrointestinal tract seen at the Duke University Hospital between 1930 and 1952 and to emphasize the curability of such lesions.

*History.* According to Raiford one of the earliest case reports of a localized lymphoma in the gastrointestinal tract appeared in 1883. A large number of reports have appeared in the literature since that time. Ullman and Abeshouse exhaustively reviewed all cases of intestinal lymphosarcoma up to 1932 and found the earlier reports to be of limited value because of the lack of an organized classification system for the various types of malignant lymphoma. Nevertheless, they believed that sufficient evidence existed to warrant a strong plea for radical surgical and radiologic attack upon these lesions. As late as 1940 Sugarbaker and Craven stated that in their experience prolonged survival was not associated with malignant lymphomas of the gastrointestinal tract. In 1942 Warren and in 1944 McSwain reported several 5 year survivors following surgery combined with x-ray treatment. Since 1942 there has been an ever-increasing number of reports on this subject, each concluding that these neoplasms can often be controlled with appropriate treatment.

*Materials.* The records of all patients with primary localized malignant lymphomas of the gastrointestinal tract at Duke Hospital from the years 1930 to 1952 were reviewed. The record library lists were checked with the autopsy reports of the Department of Pathology to include any cases of localized lymphoma that were not diagnosed clinically. Each case history was evaluated carefully and surviving patients asked to return for follow-up examination. If the patient failed to return, a standard questionnaire was sent to both the patient and the referring physician. Of 31 cases in our files, all were traced for evaluation of 5 year or longer follow-up results.

*Classification.* Even though Gall and Mallory in 1942 and Jackson and Parker in 1947 suggested a workable classification of the lymphomas, there is still a lack of agreement regarding nomenclature. Some authors still use the broad term lymphosarcoma to include all malignant lymphomas, whereas Crile believes that the lymphocytic or small cell type is the true primary lymphosarcoma. Hodgkin's disease is included by some but excluded by others. These facts make comparative statistics from the various reports difficult to evaluate. Opinions vary regarding the prognostic significance of histologic types. Marcuse and Stout felt that the clinical course could not be predicted by the histologic appearance, but Snoddy found that 11 of 13 long-term survivors up to 1952 were of the lymphocytic group. Today the excellent prognosis of giant follicular lymphoma is accepted widely, but

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some authors believe that these are not true "lymphosarcomas."

Classification of this group of tumors is based on microscopic appearance. Gall and Mallory believed that they could differentiate 7 different groups of lymphomas: (1) stem cell lymphoma, (2) clasmatocytic lymphoma, (3) lymphoblastic lymphoma, (4) lymphocytic lymphoma, (5) Hodgkin's lymphoma, (6) Hodgkin's sarcoma, and (7) follicular lymphoma. This classification was made on the basis of the predominant cell, recognizing that each of the cell types may be found in any single tumor. Other authors combine stem cell and clasmatocytic lymphomas into the reticulum cell sarcoma and the lymphoblastic and lymphocytic into lymphosarcoma. Our department of pathology has tended to use these latter combinations but specifying whenever possible whether the lymphosarcoma was lymphoblastic or lymphocytic. In our series Hodgkin's disease and giant follicular lymphoma localized to the gastrointestinal tract were not seen. The 31 cases included 8 reticulum cell sarcomas, 9 lymphoblastic lymphosarcomas, 12 lymphocytic lymphosarcomas, and 2 mixed types.

*Gross pathology.* The gross appearance of lymphomas of the gastrointestinal tract is not truly characteristic, but certain points help to differentiate it from carcinoma. At its inception it is located submucosally and may grow either as a polypoid mass (Figs. 1, 2, and 3) or as a diffuse infiltrating lesion beneath the mucous membrane (Figs. 4 and 5). This submucosal extension makes it very difficult for the surgeon to define the limits of the tumor, which explains in part the cases reported by Allen in which there was tumor present at the line of resection after supposedly adequate removal.

On cutting either the polypoid or the diffuse infiltrating types of tumor, a gray to light yellow color is noted. These tumors are firm but not hard. Necrosis and hemorrhage within the mass are seen, but even in very large lesions are rather rare. Ulceration occurs frequently and may be in the

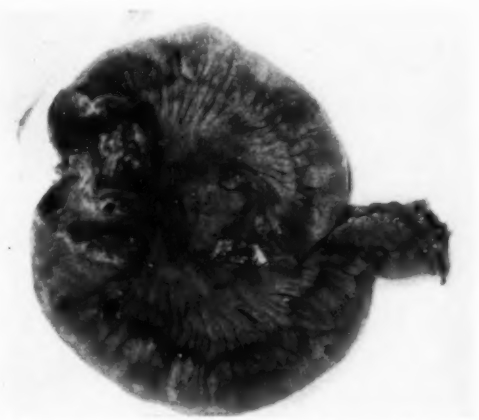

FIG. 1. Typical single ileal polypoid tumor. Note the extent of the resection. Patient alive more than 10 years after resection.

form of a single ulcer with peripheral induration and heaped up edges, indistinguishable from an ordinary gastric ulcer. More often there are multiple superficial ulcerations over the surface of larger tumors. Multiple, yet individually localized, lymphomas are said to be common in the intestinal tract, though somewhat unusual in the stomach. No example of multiple tumors was encountered in this study. When present, the lymphomas may be either polypoid or of a more diffuse spreading type which encircle the bowel producing a leather-like consistency. There seems to be a tendency for the affected bowel to dilate sufficiently to maintain flow of intestinal contents until late in the course of the disease. In the stomach lymphosarcoma can occur in any location so that its precise site is of no help in differential diagnosis. There is a well known tendency for the more distal portions of the small bowel to be affected. In our series all 11 small bowel tumors were in the ileum; 2 in the proximal portion, 3 in the midileum, 2 in the distal ileum, and 4 in the ileocecal area. This predilection for the ileocecal area was quite striking. In each of them it was impossible to say whether the tumor originated in the ileum or cecum, since bowel on both sides of the valve was

TABLE I.—CORRELATION OF DURATION OF SYMPTOMS WITH SURVIVAL IN GASTRIC LYMPHOSARCOMA

| *Duration of symptoms, mos.* | *No. of patients* | *5 year survivors* | *Intercurrent disease* | *Now living* |
|---|---|---|---|---|
| 6 or less | 7 | 1 | 1 | 0 |
| 6 to 30 | 9 | 5 | 0 | 4 |
| Over 30 | 2 | 2 | 1 | 1* |

* 26 years postoperative.

TABLE II.—LONG TERM SURVIVAL FOLLOWING RESECTION OF LYMPHOMA OF STOMACH

| *Case* | *Age, Sex, Race* | *Type* | *Spread* | *Postop. x-ray* | *Follow-up* |
|---|---|---|---|---|---|
| LC | 54 F W | Retic. sarcoma | Nodes | + | L. 5 yrs. 9 mo. |
| HS | 38 F W | Lympho-cytic | 0 | 0 | L. 26 yrs. 5 mo. |
| IE | 43 M W | Lympho-cytic | 0 | + | L. 5 yrs. 4 mo. |
| EA | 47 F C | Lympho-cytic | Nodes | 0 | D. 5 yrs. 6 mo.* |
| AT | 57 F W | Retic. sarcoma | 0 | + | L. 6 yrs. 6 mo. |
| PH | 68 M W | Lympho-cytic | Nodes | + | D. 5 yrs. 9 mo.** |
| NG | 54 F W | Lympho-cytic | Nodes | + *** | D. 5 yrs. 10 mo.**** |

*Died of coronary heart disease; autopsy refused.
**Died of heart failure; had coronary heart disease at time of surgery.
***X-ray given at 5 years postoperatively because of recurrence.
****Died of recurrence.

involved. Partial to complete intussusception was found in 6 patients, producing in each case some degree of obstruction. Perforation occurs occasionally either to the free peritoneal cavity or more often to an adjacent loop of bowel. Our only perforating lesion was in the transverse colon.

At operation extension of these neoplasms is usually found to be by direct invasion and local lymphatic spread. Distant metastases tend to occur quite late. In our series of 18 gastric lymphosarcomas, positive lymph nodes were found in 15. Seven of these patients were beyond all hope of surgical resection, and yet not one showed hepatic, pulmonary, or other distant metastases. Four of the 9 resections with lymphatic spread showed no evidence of tumor in the period of follow-up. Eleven patients with lymphosarcoma of the small intestine had exploratory operations, and again no evidence of distant spread was noted. Of 10 resected specimens, however, 5 revealed positive lymph nodes, and all 5 patients died within 3 years. The 3 apparent cures had no evidence of lymph node invasion either at the time of resection or on microscopic study.

At autopsy 4 out of 6 patients were found to have the lymphoma still localized to the region in which it was first found. In the gastric tumors invasion of spleen, transverse colon, and pancreas was noted, but other organs were entirely free of disease. An additional patient was found to have mediastinal lymph node metastases, but again there was evidence that this was propagation from node to node from the upper abdomen. A 15 year old girl showed widely disseminated lymphoma terminally after a radical resection of an ileocecal tumor. Here again primary spread had been by local extension. This case was the only one with known blood borne metastases.

### GASTRIC LYMPHOSARCOMA

*Clinical features.* In this series the average age for gastric lymphomas was 52 years with a range of 14 to 75 years. There were 7 males and 11 females. The duration of symptoms prior to treatment ranged from 2 to 12 years. The possible error in attributing a symptom of long duration to a specific pathologic process found at operation is recognized; nevertheless, many of these patients had symptoms for a long period of time prior to treatment. Another interesting fact, as has been observed in other neoplasms, is the apparent increased chance of survival in those with long clinical histories (Table I). Our one 26 year survivor had symptoms for at least 12 years, which were identical to those recorded at the time of surgery. The only recent change in symptomatology in this patient was an aggravation of the pain.

Symptomatology was in no way characteristic, but an ulcer-like syndrome was

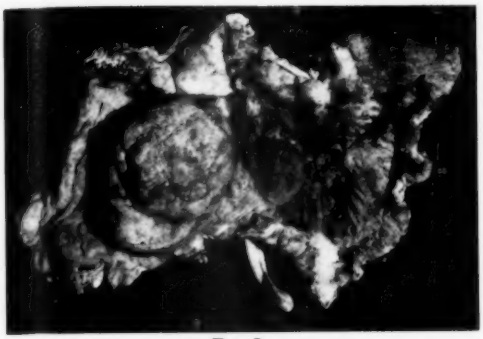

FIG. 2.

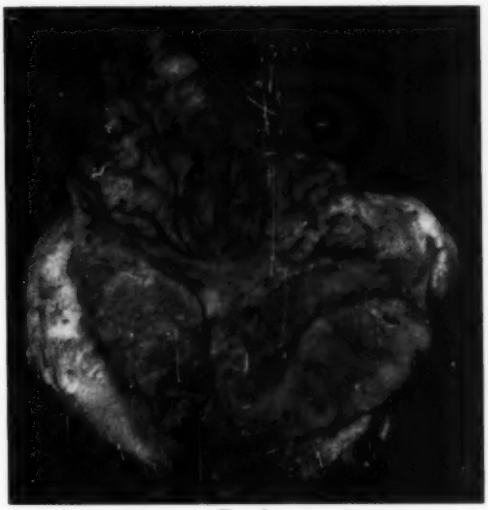

FIG. 3.

FIG. 2. A large polypoid mass at the ileocecal valve which produced obstruction. Note the ileal mucosa is to the right. This patient died 2 months following operation.

FIG. 3. Bulky mass filling the antrum of the stomach. This patient is well 6 years after resection of this reticulum cell sarcoma with lymph node metastases.

seen frequently. This finding, along with the observation of rather long clinical histories in some patients, raises the possibility of lymphosarcoma developing in gastric ulcers. Further analysis of symptoms in these 18 patients revealed that 16 had lost weight exceeding 10 pounds, 15 had epigastric burning pains or aches, and 11 had nausea and vomiting. A mass was palpated in 8, and 6 had had hematemesis or melena. In general the over-all clinical appearance of these patients was much better than a similar number of patients with carcinoma of the same extent. A palpable mass while indicating a large tumor does not preclude a cure, since 2 patients with large masses are still alive 6 and 26 years after resection.

Study of the peripheral blood revealed a mild iron deficiency anemia in most cases. The only moderately severe anemias were observed in patients obviously bleeding. Anemias of the same degree as would be expected in carcinoma of the stomach were not seen. The white blood cells were normal in each of the cases with no lymphocytosis. (Cutler and associates have reported the terminal development of lymphocytic leukemia in 2 children with gastrointestinal lymphosarcoma.)

Radiologic examination was the most important single diagnostic measure. Seventeen of the 18 patients showed an abnormality, but in only 1 case was the true diagnosis suggested. On 12 occasions a filling defect was noted; 3 patients showed hypertrophied rugal folds, and 2 others mimicked a gastric ulcer. The site of the lesion within the stomach was of no help in differentiating these tumors from other gastric lesions.

*Result of treatment.* Surgery.—All 18 patients with gastric lesions underwent exploratory laparotomy. It was considered impossible or ill-advised to attempt resective surgery in 7 of these patients. Nine subtotal resections were done with the hope of cure, and 2 additional patients had resections for palliation. All resections were patterned after accepted standards with wide removal of areas of lymphatic drainage and excision of the omentum. No total gastrectomies or radical upper quadrant dissections were attempted. Of the 9 patients in whom resection was performed for cure, 7 lived for more than 5 years, only 1 died of recurrence after 5 years, 2 died of heart disease, and 4 are living and well at the present time, 5 to 26 years postoperatively (Table II). Two of the patients with "curative"

TABLE III.—LONG TERM SURVIVAL FOLLOWING RESECTION OF LYMPHOMA OF SMALL BOWEL

| *Case* | *Age Sex Race* | *Type* | *Nodes* | *Postop. x-ray* | *Follow-up* |
|---|---|---|---|---|---|
| HL | 18 M W | Lympho-cytic | 0 | 0 | L. 22 yrs. 3 mos. |
| ES | 32 M W | Lympho-blastic | 0 | 0 | L. 10 yrs. |
| RJ | 7 M W | Lympho-cytic | 0 | 0 | L. 6 yrs. |
| BD | 72 F W | Lympho-cytic | + | 0 | D. 3 yrs. 5 mos.* |

*Died of coronary occlusion. Evaluated 4 months prior to death with complete x-ray survey with no sign of recurrence.

resections died 7 months and 9 months after surgery despite radiation therapy, whereas in comparison the 2 with palliative resections survived 2 months and 2 years respectively.

Radiation therapy.—External radiation was the primary means of therapy in 6 of the 7 patients considered to have disease completely beyond the scope of surgery. Four of the 6 were believed to have received some degree of palliation as evidenced by reduction in the size of the mass and improvement in general well being. All 6 were dead within 12 months, the average time of survival being 5 months. The 2 with palliative resections were also given x-ray therapy with 1 patient surviving for 2 years.

Radiotherapy was used as a supplementary agent in 5 of the 9 patients in whom resection for cure was performed. Two patients died of their disease within 9 months despite postoperative x-ray therapy. Of the 7 long-term survivors, only 1 died of a recurrence, and this man had not received radiation prior to the appearance of the regrowth of tumor. Of the 6 remaining 5 year survivors, 4 received postoperative x-ray therapy and 2 did not.

Chemotherapy.—Nitrogen mustard was given to 2 rapidly growing irresectable lesions. In these 2 people no real improvement was noted even though bone marrow depression indicated a good therapeutic level of the drug.

LYMPHOMAS OF THE SMALL BOWEL

*Clinical features.* Malignant lymphoma arising in the small bowel is distinctly less frequent than in the stomach. Eleven cases in the over-all series of 31 were found to involve the small intestine. The age range was 7 to 72 years with an average of 35 years as compared to an average age of 52 years for the gastric lymphomas. There were 6 males and 5 females in the group. The presenting clinical picture was that of intestinal obstruction; 8 patients had colicky pain, 7 patients complained of nausea and vomiting, and 7 patients were noted to have intestinal obstruction by x-ray examination. A palpable mass, usually in the right side of the abdomen, was found in 6 patients. Weight loss of 20 pounds or more was recorded in 7 patients. It is of interest that 2 of the 3 five year survivors had not lost weight.

The duration of symptoms in this group was considerably shorter than in the gastric cases. An acute onset was frequently noted with 4 patients receiving treatment within 2 weeks of the onset of symptoms. Only 1 patient had symptoms for as long as 2 years whereas 6 had symptoms for 1 to 8 months before therapy was instituted. The early symptoms consisted mainly of cramping epigastric and midabdominal pain associated with general malaise.

In all cases the diagnosis was established only after exploration of the abdomen. In 1 patient a barium enema demonstrated an ileocecal filling defect, and the possibility of lymphoma was mentioned in the differential diagnosis. No other diagnostic tool was of particular help. The peripheral blood was free of abnormal cells in all cases, even in those patients with rapidly progressive disease.

*Results of treatment.* Surgery.—The surgical treatment of these tumors followed the lines of accepted cancer therapy with wide excision of the lesion and adjacent lymph node bearing tissue. For lesions of the terminal ileum, a right colectomy with ileotransverse colostomy was performed. For

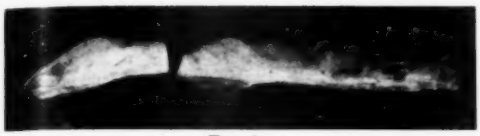

FIG. 4.

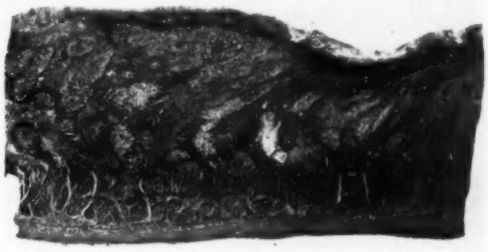

FIG. 5.

FIG. 4. Cross section of lymphocytic lymphosarcoma of stomach illustrating the submucosal extension in both directions to an indefinite termination.

FIG. 5. Photomicrograph of same patient as in Figure 4, showing typical growth pattern.

lesions of the small bowel a wide excision of the lesion and adjacent bowel and mesentery was effected. Resection was carried out in all but 1 case. The single exception was a very ill patient in whom an enteroenterostomy was done around a very large mass in the hope that resection could be accomplished at a later date. Unfortunately, this patient died within 1 month despite a course of radiotherapy. There were no operative deaths. A 15 year old girl who had direct extension of the tumor from the ileocecal valve into her right ovary and uterus required a right colectomy, a panhysterectomy, and a pelvic lymphadenectomy. Of the 10 patients with resections, 3 lived 5 years or longer and are still alive 6, 10, and 22 years postoperatively. One elderly woman died 3 years and 4 months postoperatively of a coronary occlusion, but unfortunately no autopsy was obtained. This patient had been seen in our outpatient clinic 4 months prior to her death where a complete gastrointestinal series was done, and no evidence of recurrence was found. The remaining 6 patients died within 2 years, 4 surviving for only 2 months after surgery, one 1 year, and one 2 years. The latter 2 patients had evidence of recurrence within 6 months after surgery (Table III).

Radiation therapy.—Five patients received x-ray therapy after surgery, but palliation of 6 to 8 months' duration was achieved in only 2. Three other patients failed to derive any benefit from radiotherapy. Of the 3 long-term survivors none received postoperative irradiation. The 1 patient who lived 3 years and 4 months without evidence of recurrence received x-ray therapy.

Chemotherapy.—Four patients were given TEM (tetraethelenmelamine) in an attempt to slow their rapidly progressive disease. In none of the 4 could a beneficial effect be detected. The palliation sometimes obtained with generalized lymphomas could not be duplicated in these patients.

### LYMPHOMAS OF THE COLON AND RECTUM

Two lesions limited entirely to the colon were seen, 1 in the cecum and 1 in the transverse colon. Both presented themselves with signs and symptoms of intestinal obstruction with a palpable mass. The cecal lesion was in a 6 year old male on whom a right colectomy was done without difficulty, but he died 2 months later of his disease despite radiotherapy. The lesion of the transverse colon was seen in a 51 year old man, and at operation the transverse colon was perforated. Despite a wide obstructive resection he succumbed with peritonitis on his tenth postoperative day. At autopsy a perforated cecum was found with no evidence of residual tumor. This last case represents the only operative mortality in the entire group of 31 patients.

We have no record of a lymphosarcoma localized to the rectum; however, many such cases are reported in the literature.

### DISCUSSION

Any neoplastic lesion composed of more than one type of cell is characteristically

TABLE IV.—CORRELATION OF HISTOLOGIC TYPE WITH SURVIVAL

| | | Survival | |
|---|---|---|---|
| *Cell types* | *No. of cases* | *No. of patients* | *Years* |
| Lymphocytic | 12 | 7 | Over 5 |
| | | 1 | Over 3 |
| | | 4 | Less than 2 |
| Lymphoblastic | 9 | 1 | Over 5 |
| | | 8 | Less than 1 |
| Reticulum cell | 8 | 2 | Over 5 |
| | | 2 | Over 3 |
| | | 1 | Over 2 |
| | | 3 | Less than 2 |
| Mixed | 2 | 2 | Less than 1 |

found to stimulate variations in classification as well as differences in interpretation of the clinical significance of the microscopic findings. The term lymphosarcoma means many things to many people largely because of this fact. Whereas our series is too small to draw any real conclusions, it does seem significant that of our 10 five year survivors 7 were classified as lymphocytic lymphosarcomas. Snoddy in 1952 found that of 13 long-term survivors in the gastric lymphoma group, 11 were of the lymphocytic type. Gall and Mallory also believed that the more differentiated cell type, that is, lymphocytic Hodgkin's disease and giant follicular lymphoma, carried a much better prognosis. Certainly Crile's report of 19 cases of gastric lymphocytic lymphosarcoma with 15 surviving operation and all presently alive lends credence to this point of view. On the other hand, reticulum cells can also be well differentiated or very pleomorphic, thus affecting the clinical course of the disease. Two of our long-term survivors fall into this category. Finally it should be noted that only 1 patient with lymphoblastic lymphosarcoma lived beyond 1 year (Table IV).

Whereas the pathologic anatomy still is debated, treatment has been well outlined. In earlier reports some doubt as to the feasibility of surgical resection was raised. In fact, as late as 1942 Stout found it necessary to write an editorial entitled "Is Lymphosarcoma Curable?"! Since that time many reports have appeared which support Stout in answering his question with an emphatic "yes." All agree that radical resection of these lesions is the primary treatment.

That radical surgery is a feasible approach to this problem is shown not only by the survival rate but also by the very low mortality rates quoted in most recent series. The single death in our series would probably have been a preventable death today, but in 1938 a perforated colon carried a very high mortality rate. In our series, regardless of the extent of the disease, 39 per cent of all patients with gastric lymphosarcomas entering the hospital survived more than 5 years free of recurrence. Fifty per cent of the patients with gastric lymphosarcoma were seen too late for curative resection; but of the 50 per cent resected for possible cure, 77 per cent survived for 5 years, and 66 per cent have apparently been controlled. There was a 27 per cent 5 year survival for all small bowel tumors, and of those resected for possible cure 30 per cent 5 year survivals were obtained.

Further evidence in favor of a surgical attack on these lesions can be found in the pathologic anatomy. As mentioned earlier, these tumors begin locally and tend to remain localized, often for long periods of time. As extension occurs it is almost invariably in the immediate vicinity of the tumor. Even far-advanced cases often show this striking localization with distant metastases being decidedly unusual. A situation therefore exists that is far more favorable for surgical treatment than many of the epithelial tumors. Even when nodes are present and the tumor is very large, a fair chance for cure exists. Three of our long-term survivors had metastases to the regional lymph nodes at the time of surgery.

Notwithstanding this fact there is a tendency for the diagnosis to be made when the tumor is beyond the hope of cure. Many of the patients with more rapidly progressive lesions had brief histories of the disease prior to treatment, and yet they succumbed in a short period of time. Indeed our figures indicate that with gastric lymphosarcoma a short history carries a very poor prognosis.

for the symptoms often do not appear until the lesion is very far advanced. This fact does not mean that a fatalistic attitude should be displayed toward these neoplasms, but rather it indicates the need for earlier evaluation of gastrointestinal symptoms and earlier explorations when the slightest doubt exists as to the etiology of a lesion. The use of a diagnostic laparotomy for persistent unexplained symptoms should be considered more frequently. Whereas a long clinical course may be noted in many instances of lymphosarcoma, it is nevertheless a fatal disease unless adequately treated.

What then constitutes adequate treatment? Certainly all authors since 1942 have agreed that surgical excision stands as the primary form of therapy. Only Snoddy in recent years has questioned the advisability of prescribing postoperative x-ray therapy. It is evident from Tables II and III that a difference of opinion existed on our staff in that 7 patients of the 11 long-term survivors did not receive this form of treatment. We find it difficult to discount the fact that Allen reported one well documented case of lymphosarcoma apparently cured by x-ray alone. In addition to this, it is well demonstrated that lymphosarcomas in other areas often show marked and prolonged regression with x-ray therapy. Good palliation of from 6 to 8 months was noted in several of our cases. If palliation can be achieved with large lesions by radiotherapy, it is anticipated that smaller ones may be destroyed by radiation.

Frequently in our records there existed the opinion that radiation should be withheld until there was a recurrence. This might appear to be illogical, and it may be advisable to use all available therapeutic tools initially. However, it should be noted that routine x-ray therapy in this series would have been unnecessary in 7 of the long-term survivors; the possibility that it might have obviated the single death is debatable. Also, the 4 surviving patients who did receive x-ray therapy might have succumbed to the lymphoma without radiation therapy. Therefore, the routine use of radiation therapy as a part of the complete treatment of these patients is favored. Certainly the presence of involved lymph nodes would constitute a stronger indication for this form of treatment.

Nitrogen mustard and TEM do not seem to exert any beneficial influence on the course of malignant lymphomas arising in the gastrointestinal tract. However, this study period terminated before many of the new chemotherapeutic agents became available. At the present time it appears that chemotherapy is an unknown factor for future evaluation; so far it has not played a role in the primary treatment of lymphosarcoma localized to the gastrointestinal tract.

## SUMMARY AND CONCLUSIONS

1. Thirty-one cases of lymphosarcoma limited to the gastrointestinal tract are reported with 5 year follow-up studies.

2. The histologic classification of malignant lymphomas is discussed in the light of clinical follow-up studies.

3. The tendency for these neoplasms to remain well localized for long periods of time is emphasized.

4. Salient features of clinical history and diagnosis are evaluated.

5. Seven of 18 patients with gastric lymphosarcoma lived for 5 years or longer, and 4 are alive at the present time.

6. Three of 11 patients with lymphosarcoma of the small intestine lived 5 years or longer, and all are living at the present time.

7. Wide surgical excision with postoperative x-ray therapy is recommended as the best form of therapy.

8. The prognosis for gastric lymphosarcoma is favorable if the lesion has not spread beyond the regional lymph nodes, even when the tumor is quite large.

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# DERMOID AND EPIDERMOID TUMORS IN THE CENTRAL NERVOUS SYSTEM OF ADULTS

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In 1936, Love and Kernohan reviewed experiences at the Mayo Clinic with 15 dermoid and epidermoid tumors of the central nervous system.

We have currently reviewed 45 cases of epidermoid tumor, 32 of dermoid tumor, and 10 of teratoma of the central nervous system encountered up to and including the year 1955.

We consider epidermoid tumors as neoplasms of congenital origin comprised of the outer layer of the epidermis, squamous epithelium, and desquamated epithelium—and occasionally an outer layer of fibrous and connective tissue. The stratified squamous epithelial layer contains keratohyaline granules.

Dermoid tumors are teratomas composed primarily of skin and its derivatives. They differ from the more complex teratomas which usually contain residues of tissue representing all 3 germ layers.

Adamantinomas without keratohyaline granules and characteristic stellate reticulum may be confused with some of these tumors but have not been included in this series.

In this article we shall consider for the most part the epidermoid and dermoid tumors in adults.

## EPIDERMOID TUMORS

We identified 44 epidermoid tumors of the central nervous system occurring in adult patients (15 years old or more) in our clinic before December 1955. Twenty-four occurred intracranially, 14 in the skull, 3 encroached on the orbit as well as extending intracranially, and 3 were intraspinal in location (Table I).

The tumors involving the cranial cavity orbit and skull were most frequently encountered in patients 20 to 60 years of age.

*Intraorbital tumors.* Of the 3 patients in this group, 2 were women aged 18 and 30 years and 1 was a man of 20 years at the time of operation. Each had proptosis. One patient had a palpable orbital mass; 1 had impairment of all the extraocular muscle function; 1 had papilledema. In each instance, erosion of the orbit was visible upon x-ray examination (Table II).

The tumors were removed by frontal craniotomies. None has recurred 11 months, 4 years and 8 months, and 15 years after surgery.

The results have been good.

*Intradiploic tumors.* Of the 14 patients with intradiploic epidermoid tumors, 9 were females and 5 were males. The average adult patient was 38 years of age at the time of surgery, but the age varied from 15 to 59 years.

All but 2 of these 14 patients eventually complained of headache. A variety of other symptoms occurred which could be correlated with the location of the tumor. These included a palpable tumor of the skull, a right homonymous field defect, grand mal seizures, vertigo, tinnitus, numbness of the extremities, and facial paralysis.

Palpable tumors were evident in 10 cases. Papilledema was apparent in 1 case, left hemiparesis in 1, and aphasia and right homonymous hemianopsia in another. One patient, deaf in one ear, had reduced sensation in the face from an occipital intradiploic

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TABLE I.—SEX AND SITE OF EPIDERMOID TUMORS: AGE AT DIAGNOSIS

| | *Patients* | *Per cent* | | *Site of tumors* | |
|---|---|---|---|---|---|
| | | | *Age, yrs.* | *Intraspinal* | *Others* |
| Sex | | | | | |
| Males | 18 | 41 | 15–20 | | 5 |
| Females | 26 | 59 | 21–30 | 1 | 9 |
| Site of lesion | | | 31–40 | 2 | 9 |
| Intraorbital | 3 | 7 | 41–50 | | 9 |
| Intradiploic | 14 | 32 | 51–60 | | 8 |
| Intracranial | 24 | 54 | 61–70 | | 1 |
| Intraspinal | 3 | 7 | — | | |
| Total | 44 | 100 | Total | 3 | 41 |

Age at onset of symptoms (average), 28 yrs. (2 mos.-57 yrs.)
Age at operation (average), 37 yrs. (2-65 yrs.)
Duration of symptoms (average), 9 yrs. (11 days-50 yrs.)

TABLE II.—LOCATION OF INTRAORBITAL EPIDERMOID TUMORS

| | *No. cases* |
|---|---|
| Superior and lateral wall of right orbit with extension into orbit and right frontal sinus | 1 |
| Lateral wall of left orbit with extension into temporal region of orbit and erosion of squamous part of temporal bone | 1 |
| Posteroinferior part and roof of right orbit with extension to frontal, parietal, and temporal bones (mainly intraorbital and intracranial) | 1 |
| Total | 3 |

TABLE III.—LOCATION OF INTRADIPLOIC EPIDERMOID TUMORS AND OPERATIONS PERFORMED

| *Bone or bones involved* | *No. cases* | *Operation* | *No. cases* |
|---|---|---|---|
| Parietal | 4 | Frontoparietal | 1 |
| Parietal and frontal | 1 | Suboccipital craniectomy | 1 |
| Parietal, frontal and squamous temporal | 1 | Suboccipital craniectomy and negative exploration followed by temporal craniotomy | 1 |
| Parietal and occipital (supratentorial) | 1 | Temporal craniotomy and tantalum cranioplasty | 1 |
| Occipital (supratentorial) | 2 | Removal of tumor | 10 |
| Occipital (supratentorial and infratentorial) | 2 | | |
| Occipital (infratentorial) | 1 | | |
| Temporal (squamous) | 1 | | |
| Temporal (petrous) | 1 | | |
| Total | 14 | Total | 14 |

tumor. Another patient was ataxic, and he had an occipital intradiploic tumor compressing the cerebellum. This patient had facial paralysis as the result of an intradiploic epidermoid of the petrous pyramid (Fig. 1a and b).

Roentgenograms of the skull in these cases were usually characteristic (Fig. 2); they showed involvement of both tables by a smooth, scalloped, and sclerotic margin around an area of decreased density. At times, the two tables appeared to be expanded by the neoplasm. In some instances, both tables were destroyed. In several, a curvilinear calcified structure was seen representing the intracranial wall of the tumor.

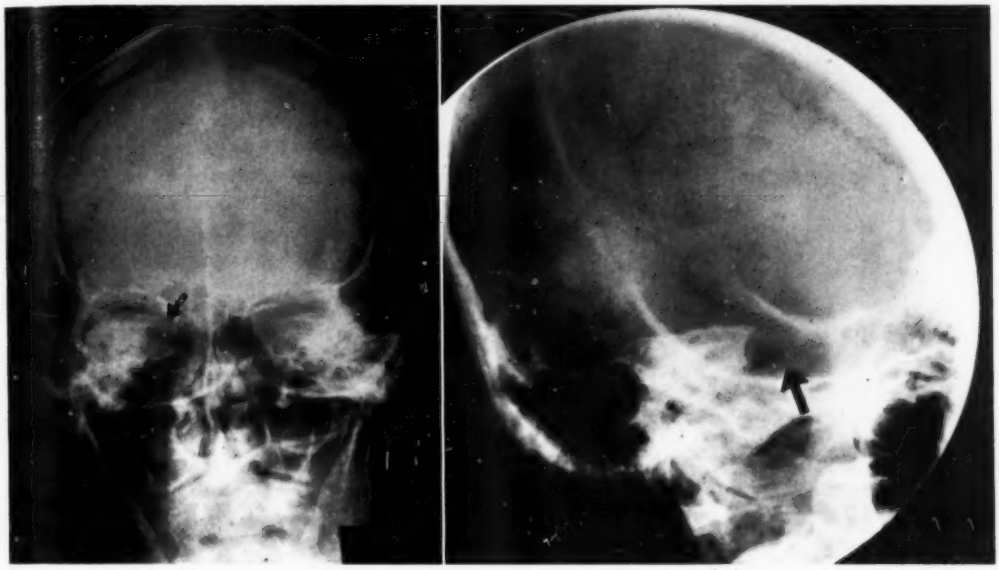
All 14 patients were treated surgically (Table III). There were no deaths and in each case the tumor was eradicated. All but 3 patients have been traced for an average of 10.7 years since operation. One patient had a second operation 7 years later for recurrence and has been traced for 7 years since then without a recurrence.

Residual neurologic defects are minimal and include a right homonymous defect, minimal aphasia, and in 1 case, persistent deafness and facial paralysis on the side of operation. In 3 instances, no information is available.

*Intracranial tumors* (*Table IV*). The most common location of the 24 intracranial epidermoid tumors was the cerebellopontile angle. Eight occurred in this location, and 7 occurred in the sella or suprasellar region, and 4 in the temporal lobe. One occurred in the region of the gasserian ganglion in the middle fossa. One was in the region of the cerebral peduncle and thalamus, 1 in the fourth ventricle, 1 in the interpeduncular cistern, and 1 was supratentorial and infratentorial, with extension into the right lateral ventricle.

Cerebellopontile angle tumors.—Three of the 8 patients with epidermoid tumors of the cerebellopontile angle were men and 5 were women; their ages ranged from 20 to 50 years. In 4 patients the symptoms and objective findings suggested cerebellopontile or pontile syndromes. Three had trigeminal neuralgia and 1 complained only of headache and stiff neck.

Operations were performed on the 4 patients with cerebellopontile angle syndromes. Three tumors were completely removed. One was incompletely removed. One whose tumor was totally removed died in the hospital. The patient whose tumor was removed subtotally has not been heard from since dismissal. The 2 other patients are alive and essentially well but have some neurologic



a b

FIG. 1. a and b, Erosion of the petrous pyramid by an epidermoid tumor.

residuals. Both have had spinofacial anastomosis because of facial paralysis.

The 3 patients with trigeminal neuralgia were a man, aged 31 years, and 2 women, aged 32 and 47 years. The second and third divisions of the nerve were involved in 2 instances and the third division in the other. Neurologic findings for the 2 women were normal. The third patient's pain subsided after nystagmus, inco-ordination, tremor, masked facies, and bilateral Babinski signs developed. He died of intestinal obstruction 21 years after the onset of these symptoms and his tumor was discovered at necropsy. Operation relieved the pain of the 2 women.

The patient with a cerebellopontile epidermoid without localizing neurologic changes was 24 years of age and had had intermittent headache and stiffness of neck for 20 years. Examination revealed papilledema. Ventricular studies and suboccipital craniectomy revealed an epidermoid tumor extending from the right internal auditory meatus to the upper cervical portion of the vertebral canal. The tumor was subtotally removed, and 22 years later, the patient was still asymptomatic and was the mother of 2 daughters, aged 19 and 15 years.

In the region of the sella turcica.—Seven patients are included in this group. Four were women and 3 were men; ages ranged from 16 to 55 years. Five of these patients complained of headache, and all had visual complaints. Three with seizures also had deteriorated mentally, and 1 had clinical evidence of hypothalamopituitary insufficiency.

Examinations of the ocular fields revealed involvement of an optic tract in 1 patient, chiasmatic defects in 3 patients, and optic nerve and chiasmatic defects in the 3 remaining patients. Five had some degree of optic atrophy (bilateral in 4 and unilateral in 1). One patient had a blind eye with a dilated pupil which only reacted consensually to light. None of the patients had involvement of the extraocular nerves.

By roentgenographic examination the skull was found to be normal in 3 patients. In 1 case, roentgenography revealed flattening of the tuberculum, in another, flattening of

FIG. 2. An intradiploic tumor involving both tables of the skull with a smooth, scalloped sclerotic margin around an area of decreased density.

the tuberculum sellae with erosion of the posterior clinoids, in a third destruction of the dorsum sellae and erosion of the floor of the sella, and in the fourth erosion of the left optic canal. Not included in this series is a recent instance in which calcium was observed in an epidermoid tumor in this area.

Carotid angiograms were made in 2 cases but were of minimal diagnostic value. In 2 cases, air studies were made which outlined the tumors.

Operations were performed in these 7 cases. Two patients have been operated upon more than once. One who was operated on twice died 4½ months after the first operation. The other was operated on 22 months and again 4 years after the original operation. She died 4 years and 3 months after the original operative procedure.

There was another postoperative death in a 16 year old boy in whom the tumor had not been completely removed.

Four patients are alive. Two are thought to have had complete removal of their tumors and 2 are known to have had incomplete resection. These 4 patients have been traced from 8 months to 18 years. The 2 who have had incomplete removal of their tumors are alive, 14 months and 18 years after operation.

Temporal lobe.—Of the 4 patients who had epidermoid tumors confined to this area or sylvian fissure, 2 were men and 2 were women. Their ages at the time of diagnosis were 29, 31, 40, and 42 years. Symptoms had been present for from 9 months to 21 years. Headaches and grand mal or temporal lobe seizures occurred in 3 patients. One patient was stuporous on admission. In addition, 1 had homonymous hemianopsia and another had papilledema. Two patients were ataxic, and 1 patient had mild hemiparesis.

Roentgenograms of the skull were negative in 1 case; secondary pressure erosion of the clinoid processes was noticed in 1 case and a shift of the pineal body away from the neoplasm in 2 cases. Ventriculography in 2 instances revealed a pineal mass on the right in 1 instance and a cyst communicating with the right temporal horn in the other. A left carotid angiogram in 1 case revealed the presence of an avascular tumor in the left sylvian region.

Operation was attempted in all 4 patients. Three patients died 19 days, 31 days, and 4 months after operation. The 1 survivor had a tumor of the left sylvian fissure. He has been well for 4 years except for occasional seizures that are well controlled with dilantin sodium.

TABLE IV.—LOCATION OF INTRACRANIAL EPIDERMOID TUMORS

| *Location* | *No. cases* | |
|---|---|---|
| Cerebellopontile angle | | 8 |
| Right 3; left 4 | 7 | |
| Right, anterior to pons and medulla, right internal auditory meatus, lateral to medulla and upper cervical part of cord | 1 | |
| Sellar or suprasellar region | | 7 |
| Intrasellar | 4 | |
| Intrasellar, suprasellar, and right basofrontal | 1 | |
| Intrasellar, suprasellar, interpeduncular, and right middle fossa | 1 | |
| Suprasellar, bilateral basofrontal, and left middle fossa | 1 | |
| Temporal lobe | | 4 |
| Right, intraventricular | 1 | |
| Medial right | 1 | |
| Right, parasellar and middle fossa | 1 | |
| Left wall of sylvian fissure and wall of temporal horn | 1 | |
| Combined supratentorial and infratentorial | | 1 |
| Miscellaneous | | 4 |
| Total | | 24 |

The tumors of the patients who died were located near the pineal body, in the temporal horn of the right lateral ventricle, and in the substance of the temporal lobe attached near the hypophysis.

Combined supratentorial and infratentorial epidermoid tumors with extension into the right lateral ventricle.—In 1 case the epidermoid tumor occurred both above and below the tentorium and incidentally encroached on the temporal horn of the right lateral ventricle. Symptoms began in 1944, and the patient was operated on in December 1955. At that time, he was bedridden with cerebellar, midbrain, and supratentorial defects of great magnitude. On ventriculography, the tumor seemed to arise in the region of the basal ganglia on the right and had the irregular outline of an intraventricular tumor described by Krieg, Dyke and Davidoff, Childe and Young, Shapiro, Hauser and Elkins, and Schulze (Fig. 3a and b). Right temporal craniotomy was performed; temporal gyrectomy revealed the tumor presenting on the medial wall of the temporal horn. The ependyma and capsule of the tumor were incised and the contents removed. The tumor extended between the nerves and vessels of the middle fossa and down through the tentorial notch into the posterior fossa. It was removed from both fossae exposing the posterior cerebral artery and basilar artery in the region of the tentorial notch and posterior fossa. The patient survived with the additional defect of left homonymous hemianopsia. Two years later in January 1957, he was still improving and could walk a distance of a city block.

Miscellaneous intracranial epidermoid tumors.—There were 4 patients in this group.

A 59 year old woman had trigeminal neuralgia from an epidermoid tumor of the right gasserian ganglion and a right parasagittal meningioma. Both were successfully removed.

Another patient, a 27 year old man, died without surgical investigation of an epidermoid tumor in the region of the left cerebral peduncle and thalamus. The patient also had a pinealoma.

a

b

FIG. 3. a and b, An epidermoid of the temporal lobe extending into the lateral ventricle. This is a good example of the irregular outline produced by these intraventricular tumors.

Another patient died of a perforating gastric ulcer and pulmonary embolus. Necropsy revealed an epidermoid of the interpeduncular region.

The fourth patient was a 32 year old woman whose tumor occurred in the fourth ventricle without a dermal sinus. She had papilledema, stupor, and other evidences of increased intracranial pressure. She died on the operating table on June 19, 1931. This incidentally was the third intraventricular epidermoid in the entire series.

TABLE V.—RESULTS OF OPERATIONS FOR EPIDERMOID TUMORS

| | Site of tumor | | | |
|---|---|---|---|---|
| | *Intradiploic* | *Intraorbital* | *Intracranial* | *Intraspinal* |
| Operations | 14 | 3 | 21 | 3 |
| Tumor: completely removed | | | | |
| Yes | 14 | 3 | 11 | 2 |
| No | | | 8 | 1* |
| Unknown | | | 2 | |
| Hospital deaths | 0 | 0 | 4 | 0 |
| Died in 4 mos., cause unknown | | | 1 | |
| Follow-up data | 11 | 3 | 8 | 2 |
| Recurrences | | | | |
| Yes | 1 | 0 | 2 | 0 |
| No | 10 | 3 | 6 | 1 |
| Uncertain | | | | 1* |
| Duration of follow-up in cases of no recurrence | | | | |
| Average, yrs. | 10.7+ | | 7.3 | |
| Range, yrs. | 3.2–16 | 0.9–15 | 1.3–22 | 5.3–12 |

*Patient complained of numbness and pain in thighs on questionnaire 5 yrs. and 4 mos. after operation.

*Intraspinal epidermoid tumors.* The 3 adult patients in our series were 2 women, 32 and 38 years old, and a man, 26 years old.

The man had an intradural extramedullary tumor at the level of the third and fourth lumbar vertebrae. He had sciatica of 1 year's duration. Results of neurologic examination were normal. His spinal column listed toward the left with a loss of lumbar lordosis and limitation of back motions. Roentgenograms of the spinal column showed normal conditions. Myelography revealed a tumor which proved to be an epidermoid. It was completely removed without permanent neurologic disability.

The 38 year old female patient had backache and bilateral sciatica. The ankle reflexes and knee reflexes were reduced, but no other neurologic defects were found. Roentgenograms of the spinal column revealed erosion of the twelfth thoracic and first lumbar vertebrae. The tumor was outlined by myelography. At operation the tumor was partially removed. Findings at a later examination were normal except for diminished knee reflex on the left and hypesthesia in the region innervated by first sacral nerve on left.

The 32 year old woman with an intramedullary conus medullaris tumor had had symptoms since the age of 14 years. These were bladder and bowel incontinence. Examination revealed saddle anesthesia and sacral and lumbar motor defects. Roentgenograms revealed erosion of the spinal canal from the twelfth thoracic to the second lumbar vertebrae. The tumor was in the conus and filum. Complete removal was accomplished. Findings on neurologic examination were unaltered by this procedure. Five years and 4 months later she was pregnant but unaltered neurologically.

No adults with intraspinal epidermoid tumors had congenital dermal sinuses.

*Summary of results of treatment (Table V).* The 14 intradiploic epidermoid tumors were removed without a death and only 1 tumor recurred. Three intraorbital tumors were successfully removed.

Twenty-one of 24 intracranial epidermoid tumors were treated surgically: 11 were removed completely, 8 were incompletely removed, and 2 were not known to be completely or incompletely eradicated. There were 4 hospital deaths. Of the 17 patients who survived operation, 1 died in 4 months. We have follow-up data on 8 patients an average of 7.3 years after operation; 2 have recurrences and 6 do not.

The 3 adult patients with spinal epidermoid tumors have survived.

DERMOID TUMORS

Thirty-two dermoid tumors were verified in our series from 1927 through 1955. Twenty of these were in males and 12 in females. Nineteen were in adults and were located as follows: intracranial in 9, intradiploic in 4, intraorbital in 1, and intraspinal in 5.

*Intracranial supratentorial dermoid tumors.* Six of our intracranial dermoid tumors in adults were supratentorial (Table VI). The ages of the patients ranged from 24 to 43 years. Five of the patients were men and 1 was a woman. Four of the lesions were located within or adjacent to the sella turcica, and 2 were in the right frontal lobe.

Neurologic findings in all 6 cases were compatible with the location of the tumor.

By roentgenographic examination the skulls were found to be abnormal in all instances. These included enlargement of the sella, calcification in the suprasellar neoplasms, erosion of the dorsum and floor of the sella, and destruction of the posterior clinoid processes. One tumor in the frontal lobe had visible calcium by x-ray examination as did 3 of the suprasellar neoplasms. Pneumograms were done in 2 instances outlining the neoplasms.

All 6 patients were operated on, but only 1 tumor was removed completely. The latter patient was alive 18 years and 5 months later, but was still having occasional seizures. Her lesion was a bilateral basofrontal and right temporal lobe tumor. There were 2 hospital deaths in the group on the fifth and twelfth postoperative days. One patient was alive and well 7 years and 8 months after incomplete resection of the tumor. Another was alive and well 16 years and 4 months after operation. The sixth patient has not been contacted.

*Intracranial infratentorial tumors* (*Table VI*). The other 3 adult patients with intracranial dermoid tumors had infratentorial lesions. All were females who were 20, 29, and 30 years of age. None had dermal sinuses or skull defects. All were successfully operated on and are alive without recurrences.

*Intradiploic dermoid tumors*. All but 4 of the 11 intradiploic dermoid tumors were identified in children. Nine patients were males, and 2 were females.

The 4 adult patients were men, aged 51, 37, 27, and 25 years. Three had symptoms suggestive of intracranial extension, such as headache, but no neurologic changes were noted. Roentgenographic appearance of the skull was similar to the appearance when intradiploic epidermoid tumors were present.

The tumors of the adults were successfully removed. There were no deaths or recurrences although the follow-up on 2 patients has not been adequate.

*Intraorbital tumor*. The 1 patient with an intraorbital tumor was a 43 year old man. He had a history of unilateral proptosis of 13 years' duration. Seven years after the onset of symptoms, the right orbit had been approached laterally and "greenish pus" was encountered behind the globe. Twelve years after symptoms had begun, the patient again noted that his right eye was becoming more prominent. Examination revealed a mass behind the globe and definite proptosis. Vision and ocular motions were normal. On October 3, 1950, the tumor was removed except for a small piece of capsule attached to the globe. A frontal approach was utilized. The patient had survived 5 years and 10 months at time of follow-up examination.

TABLE VI.—SITE OF INTRACRANIAL DERMOID TUMORS

| *Site* | *No. cases* |
|---|---|
| Supratentorial lesions | |
| Intrasellar and suprasellar | 1 |
| Suprasellar and basofrontal | 1 |
| Bilateral basofrontal and right middle fossa | 1 |
| Right frontal lobe and attached to circle of Willis | 1 |
| Right frontal lobe | 1 |
| Left frontal lobe extending into right frontal lobe and to pituitary stalk | 1 |
| Total | 6 |
| Infratentorial | |
| Left cerebellar hemisphere | 1 |
| Both cerebellar hemispheres and vermix | 1 |
| Vermis and 4th ventricle | 1 |
| Total | 3 |
| Grand total | 9 |

*Intraspinal dermoid tumors*. Five patients with spinal dermoid tumors were adults. Three of them were men and 2 were women.

Three adults had intradural intramedullary tumors of the conus and filum. One had an intradural extramedullary tumor of the cauda equina. One had a low lumbar caudal tumor with a spina bifida. None had dermal sinuses.

Findings on neurologic examination varied from normal to evidence of bilateral involvement of the lumbar and sacral nerve roots. Roentgenograms revealed spina bifida of varying degree in 3 cases and widening of the space between pedicles in 1 instance. Myelography was utilized in 3 instances to outline the tumor. Values for total protein in the spinal fluid varied from 440 to 20 milligrams per 100 cubic centimeters. The cell counts were normal.

Of the 3 patients with intramedullary tumors of the conus, 1 had complete removal of the tumor and 2 had incomplete removal. One patient with an intradural extramedullary tumor of the cauda equina had complete removal with sacrifice of adherent nerve roots. One patient, a 26 year old man, had a dermoid weighing 670 grams and associated spina bifida occulta. This dermoid was completely removed.

Two patients with intramedullary conus lesions needed transurethral resections of the neck of the bladder postoperatively because of urinary retention.

Bowel and bladder management have been troublesome problems as expected.

SUMMARY

This review was based on 77 cases of epidermoid and dermoid tumors of the central nervous system encountered at the Mayo Clinic before December 1955. Details are given concerning the patients 15 years of age or older, 44 of whom had epidermoid tumors and 19 of whom had dermoid tumors. Discussion then has been limited to the 63 adult patients.

Both epidermoid and dermoid tumors are considered to be congenital in origin. The dermoid tumors are the most frequently seen in conjunction with a dermal sinus except in adults and appear symptomatically earlier in life than the epidermoid tumors. The dermoid tumors seem to present calcification more frequently in the x-ray studies. Congenital anomalies were associated with 3 of the epidermoid tumors and with 50 per cent of the dermoid tumors. These anomalies included anomalous fusion of various vertebrae, cyst of the septum pellucidum, presence of dermal sinuses, harelip, pilonidal sinus, cysts under the occipital portion of the scalp at birth, cervical rib, meningocele, and spina bifida.

A surprising number of patients with both groups of tumors involving the intracranial, intraorbital, or intradiploic areas had mental symptoms.

The hospital mortality rate after operation for epidermoid tumors on the adults was 4 in 41 cases (9.7 per cent). There were 3 operative deaths in the 32 cases of dermoid tumors with a hospital mortality rate of 9.3 per cent. Long survival may occur in these cases, even though the tumor is incompletely removed.

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# USE OF PLIABLE SYNTHETIC MESH IN THE REPAIR OF HERNIAS AND TISSUE DEFECTS

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HERNIAS and tissue deficiencies are encountered which require the addition of a reinforcing or bridging material to obtain proper repair. The need for a satisfactory reinforcing material is attested to by the number of substances that have been used ranging from tissues such as skin, fascia, dura, scar, cartilage, and bone to various types of metals and synthetic plastics. In our experience, a pliable synthetic mesh with interlocked fiber junctures appears to serve as a satisfactory prosthesis when properly employed. It adds maximum strength with minimum foreign substance. In this report certain applications and limitations of pliable, porous, synthetic prostheses will be presented based upon animal experiments and clinical experiences with 33 patients.

## MATERIALS AND METHODS

A nylon mesh with interlocked fiber junctures (Fig. 1) was used in the initial phase of the study. It was soon replaced by a somewhat similar but stronger nylon mesh (Fig. 2). This type of mesh is knitted, but it has also been referred to commercially as a tulle type of weave. An open type of weave may be called mesh or net; when closely woven it appears as cloth. The mesh is made from fibers that are machine knitted. The knitting process results in the fiber junctures being interlocked in a way that prevents unraveling. The mesh is then washed with a detergent, thoroughly rinsed, and dried. It is next spread on frames and exposed to reflected heat; this sets the interlocked fiber junctures. After this processing by the manufacturer, the mesh is ready for distribution in a soft pliable form. It need only be exposed to routine autoclave sterilization and it is ready for use in surgery.

Another form of nylon mesh, dermalon nylon mesh U.S.P., (Fig. 3) was given limited trial. This material is woven in the form of a simple basket-type weave as seen with tantalum or stainless steel mesh. The fiber junctures are fused to prevent slipping. This mesh is manufactured in certain sizes as squares, ovals, and rectangles. It has an electronically fused edge to aid suturing and to prevent fraying. However, it was not possible to cut the material to desired size at surgery for with the special edge trimmed away the fused fiber junctures came apart when subjected to the pull of sutures.

Another form of woven mesh, made from teflon, is shown in Figure 4. This is an interwoven type of basket weave. It has the disadvantages of fiber junctures slipping, and a marginal cuff is needed for suturing. Teflon appears brown in the commercial form available to us, and it was necessary to subject the material to acid soaks to remove the carbonaceous impurities and obtain the purer white fiber. The teflon mesh was used in animals, with and without bleaching, but it was not used in humans.

## CLINICAL EXPERIENCE

A synthetic mesh has been used in 33 patients, in 22 of whom various types of chest wall defects were bridged, and in 11 abdominal hernias and deficiencies were reinforced or bridged. A mesh of nylon with interlocked fiber junctures was used in most cases, but in 3 mastectomy patients the mesh

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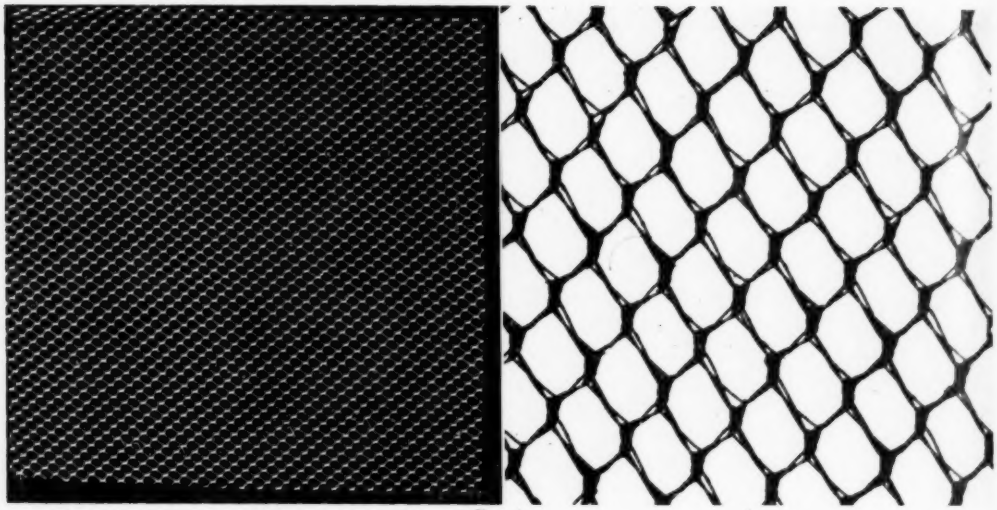
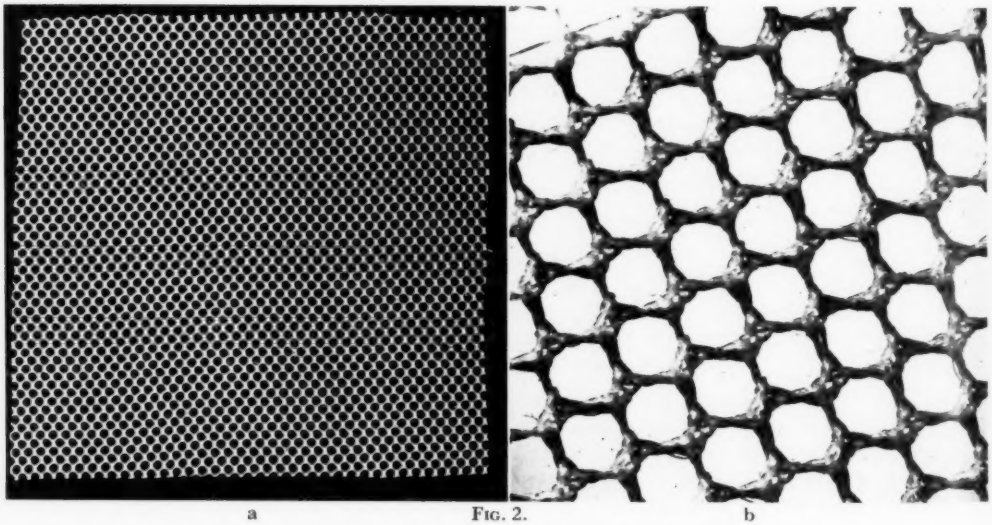


a FIG. 1. b

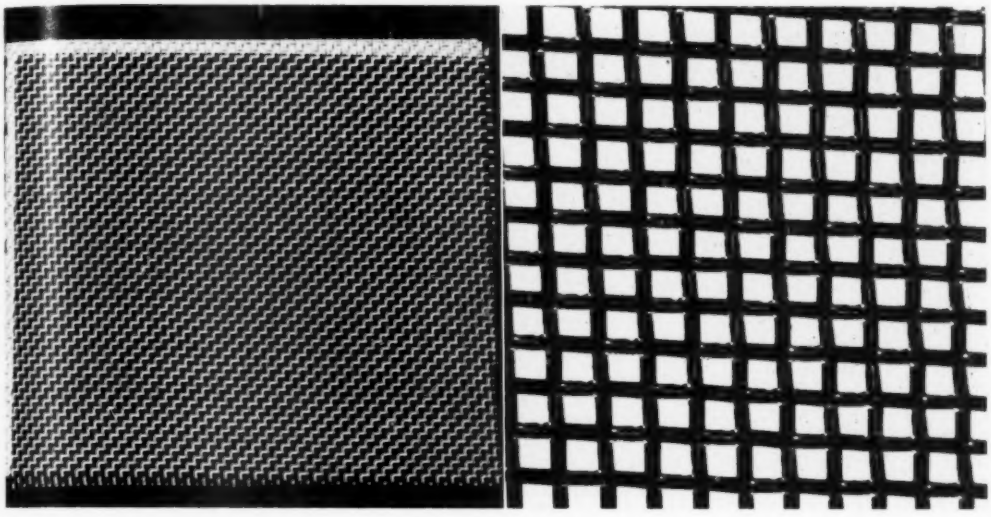


a FIG. 2. b

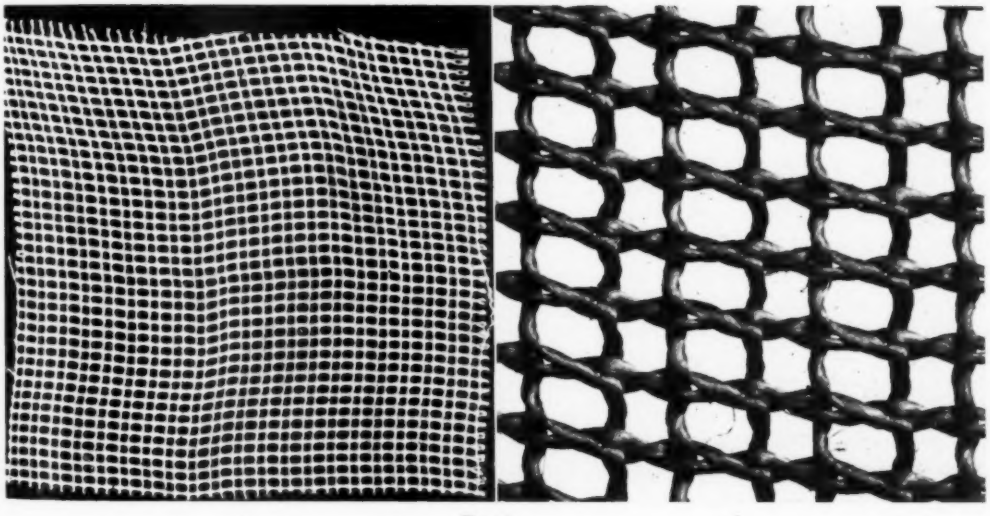
FIG. 1. Knitted nylon mesh showing interlocked fiber junctures. a, Gross appearance. b, Photomicrograph, approximately × 17.

FIG. 2. Knitted nylon mesh showing interlocked fiber junctures. a, Gross appearance. b, Photomicrograph, approximately × 17.

with fused fiber junctures was used. In the most recent ventral incisional hernia, a knitted mesh of dacron with interlocked fiber junctures was used rather than nylon (Figs. 5 and 6). Dacron knitted mesh (mersilene) has been used in the repair of 2 additional recurring ventral hernias and 1 recurring inguinal hernia. In the inguinal hernia the lower edge of the mesh was sutured directly to Cooper's ligament. The results to date have been satisfactory. This dacron mesh has the same gross appearance as the nylon mesh of Figure 2, and it is processed in a similar way.



a FIG. 3. b

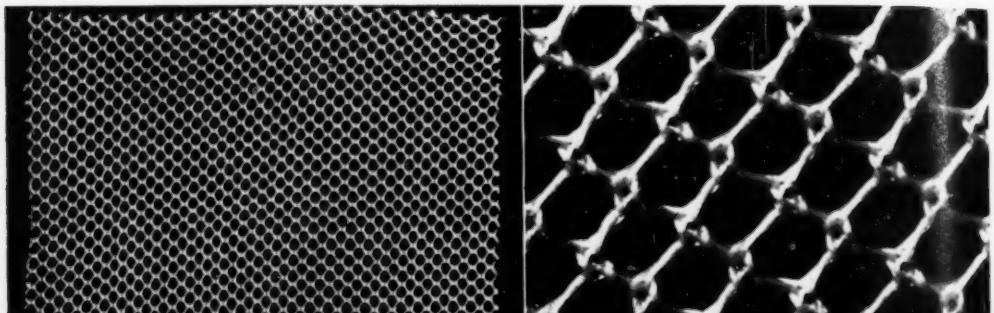


a FIG. 4. b

FIG. 3. Woven (basket weave) nylon mesh with fused fiber junctures. a, Gross appearance. Note the special electronically fused border on top and left sides. The mesh was purposely cut on bottom and right sides to show how unraveling may occur without this edge. b, Photomicrograph, approximately × 17.

FIG. 4. Woven (interlocked basket weave) teflon mesh. a, Gross appearance of white acid-bleached mesh. Note fraying. b, Photomicrograph of unbleached mesh, approximately × 17.

*Chest wall defects.* In 18 women undergoing the Urban type of extended radical mastectomy with internal mammary node dissection, the surgical defect of the bony thoracic wall was bridged by nylon mesh; 15 were knitted mesh and 3 were woven fused mesh. In this type of extended radical mastectomy, the second through fifth costal



a b

FIG. 5. Knitted dacron mesh showing interlocked fiber junctures. a, Gross appearance. b, Photomicrograph, approximately × 17.

cartilages and adjacent lateral sternum were resected leaving a defect in the thoracic wall of approximately 6 by 9 centimeters. The mesh bridging the thoracic defect was sutured to the periosteum of the surrounding ribs and sternum. It was in contact with the lung below and with the skin flaps above. Ten mastectomies were performed on the right side and 8 on the left side. All patients have been followed up in the out-patient clinic from 3 to 16 months after surgery with an average time interval for the group of 10½ months.

Five breast wounds became infected postoperatively following varying degrees of skin flap separation which exposed the underlying mesh. These wounds continued to drain through 1 or more sinuses. Four involved interlocked mesh and 1 the woven fused mesh. All were on the right side. In 1 of the 5 infected wounds there was a low grade osteomyelitis in the lateral aspect of the partially resected sternum; the diseased bone was excised at reoperation. In another there was a localized empyema beneath the mesh which became obliterated following drainage. The mesh was purposely excised in all 5 patients at the time of reoperation and the wounds healed. At the time of reoperation, there were redundant edges of loose mesh in all infected wounds, but the main part of the mesh was well incorporated with the underlying tissue. It was necessary to remove the adherent areas of mesh by traction and sharp dissection. In 1 other infected wound a small area of the incision separated, but with early proper drainage the wound healed without need for removing the exposed underlying mesh.

In 4 other patients, surgical defects of the chest wall were bridged by the interlocked nylon mesh. In these patients, the mesh was in direct contact with the underlying lung. In a 6 year old boy, the right anterolateral segments of ribs 6 and 7 were excised for a symptomatic osteocartilaginous exostosis. Knitted nylon mesh was sutured across the defect, and the wound healed primarily without drainage. Only minimal postoperative paradoxic motion was noted on deep respiration. There were no complications when he was last observed 7 months later. The second patient, a 56 year old male, had a large recurring cystic tuberculous

lesion of the wall of the left side of the chest following segmental pulmonary resection for tuberculosis 3 years previously. The postoperative cystic lesion had been needled and partially excised at another hospital. On admission to the Buffalo General Hospital, the lesion was widely excised including the posterolateral segments of ribs 6, 7, and 8 to which the lesion was intimately attached. The resulting defect in the costal cage was approximately 8 by 12 centimeters. It was bridged by knitted nylon mesh. The wound healed satisfactorily, but a mild bulge was present with coughing and a moderate degree of paradoxic motion was apparent with forceful respirations 8 months later. In the third patient, a 25 year old female, the lateral segments of ribs 7 and 8 and part of the upper left abdominal musculature were excised for a chondrosarcoma. The wound separated and became infected postoperatively, and a small piece of underlying free mesh was excised. After adequate drainage, the remaining mesh became covered with granulation tissue and the wound healed satisfactorily. In the fourth patient, an 11 year old boy with a growing rib mass 1 year after trauma, a wide resection of the right anterolateral portions of ribs 6 and 7 with the adjacent muscles was performed. Grossly, this lesion was thought to be a chondrosarcoma, but histologically it proved to be chronic osteomyelitis with abscess formation. Knitted nylon mesh was sutured across the defect and the wound healed primarily. Slight paradoxic movement with forceful respiration was apparent 1 year later.

*Abdominal wall defects.* This group of 11 cases included 8 ventral incisional hernias, 2 inguinal hernias, and an abdominal wall defect that was created following wide excision of an invading carcinoma of the cecum. Of the 8 incisional hernias, 4 were primary repairs and 4 were recurrences following from 1 to 5 previous repairs. In 3 of this last group, tantalum mesh had been implanted in the previous repair. In 2 of the 8 incisional hernias, a musculofascial defect

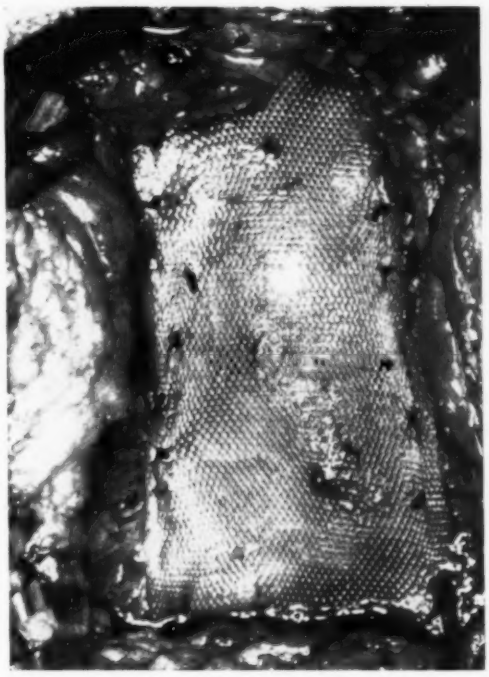


FIG. 6. Close-up partial view of dacron mesh reinforcing attenuated area of recurring ventral incisional hernia repair.

was bridged by knitted nylon mesh. In the others, the knitted mesh was used as a reinforcing prosthesis. The sheet of mesh was sutured widely over the attenuated repair using interrupted sutures of silk or nylon according to the surgeon's preference. The sutures were placed into substantial fascia parallel with the mesh edge and about 3 interspaces of mesh were anchored with each bite. After all marginal sutures were placed and the excess mesh trimmed away, a free edge of mesh extended 3 to 4 millimeters beyond the sutures. Both inguinal hernias were in older males whose tissues were too weak for an otherwise adequate repair (Fig. 7).

All hernia wounds healed without infection. In only 1 was a soft rubber drain placed at the time of surgery. In another a collection of serum drained spontaneously through the wound. In 1 other, a subcutaneous collection of serum was removed by

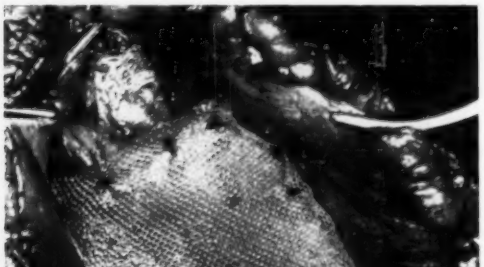


FIG. 7. Bassini type repair of direct and indirect right inguinal hernia with reinforcing sheet of knitted nylon mesh. Slit cut in mesh near area of internal ring for spermatic cord which is retracted down and to viewer's left. External oblique aponeurosis to be closed over spermatic cord and synthetic mesh.

needle aspiration. The hernia patients have been observed postoperatively for a period up to 28 months with an average of 13 months. There have been no late complications or recurrences. In the patient with abdominal wall invasion from carcinoma of the cecum, a wound infection developed following right hemicolectomy. At the time of hospital discharge a small sinus draining sanguineous fluid remained. Unfortunately, this patient was lost for follow-up.

## DISCUSSION

Because occasional hernias and deficiencies cannot be adequately repaired by using existing tissues, the search for a satisfactory reinforcing substitute continues. It is hoped that the ideal material may be developed from one or more of the increasing number of modern synthetic materials. From our observations to date, there appear to be a number of advantages to the use of a reinforcing sheet of pliable plastic mesh with fixed interlocked fiber junctures. A porous mesh of the simple woven and braided types would seem to be less desirable than a knitted one in which the fiber junctures are fixed by interlocking so as to prevent slipping and unraveling.

In contrast to relatively impermeable substances such as skin, fascia, preserved dura and plastic sheets, serum cannot be trapped beneath the porous prosthesis. Fibrovascular tissue can grow through and incorporate the mesh in the tissues with which it has contact. Unlike the more rigid metallic meshes, however, projection through skin or erosion into an adjacent blood vessel or viscus has not been observed. The sites of fiber junctures do not appear to be subjected to the same forces of work fatigue that have been seen with the more rigid metallic meshes. The pliability of the synthetic mesh allows for better adaptation to the various stresses encountered in the body. In fact, the knitted type of mesh exhibits a degree of functional elasticity or stretch as the prosthesis is pulled in one direction and then another.

The mesh is made ready for use in surgery by routine sterilization in an autoclave. Its interlocked fiber junctures prevent slipping and distortion, allow it to be cut to any size or shape at surgery, and permit marginal suturing without need for a cuff to prevent unraveling. Another desirable feature is that the mesh may be safely placed in direct contact with abdominal and thoracic viscera when peritoneum and pleura are absent. Our animal studies have shown that the mesh becomes covered by a thin glistening fibrous layer and it remains soft and pliable. The mesh does not noticeably interfere with normal wound healing.

A most important consideration is the material from which the mesh is made. Nylon was inexpensive and readily available for use in the initial phase of evaluating the

principle of an open type of pliable synthetic prosthesis. Unfortunately, nylon loses a large part of its tensile strength in the body because of its hydrophilic properties and basic chemical structure. These undesirable features would appear to disqualify nylon from further consideration as a supporting prosthesis in the body (Fig. 8) although we have seen nylon mesh remain intact in animals for periods over 2 years.

More recently we have changed to a similarly knitted mesh with interlocked fiber junctures only made of dacron (Fig. 5). Dacron is not subject to the degree of chemical degradation and loss of tensile strength as is nylon. Teflon, another synthetic plastic, has certain features of durability and inertness that are attractive, and a somewhat similar type of mesh with interlocked fiber junctures can be made from this material. Teflon requires additional chemical treatment after its manufacture to remove certain carbonaceous impurities. It is somewhat more difficult for weavers to handle, the fibers are larger, and it is more expensive than nylon or dacron. Nevertheless, teflon has many properties that make it close to an ideal synthetic material when obtained in proper form. The pertinent physical chemical properties of these and similar synthetic materials cannot be reviewed here but this important information is now available in the more recent surgical literature as well as in technical manuals.

Regardless of the material or combination of materials eventually found to be most desirable, the essence of the matter appears to be that the mesh must be durable and maintain its tensile strength, or it will have no value as a supporting prosthesis. One cannot depend upon scar tissue to take over support if the prosthesis fragments or disintegrates; 3 of the incisional hernias that we encountered had recurred through areas of fragmented tantalum mesh despite the excessive deposition of fibrous tissue so commonly seen in response to implanted tantalum mesh. The advantages of a water repellent material that causes no tissue reaction

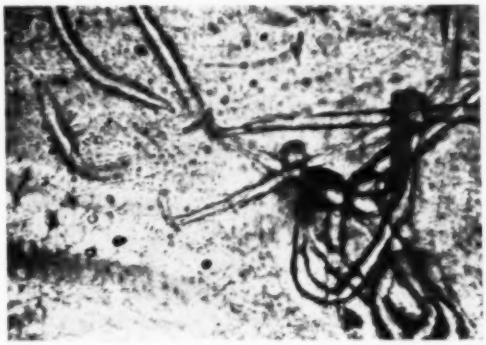


FIG. 8. Photomicrograph of nylon mesh of type shown in Figure 1, approximately × 55. Mesh used to replace left hemidiaphragm of dog, removed 2 years after implantation. Several areas of mesh had stretched and fragmented. Interlocked fiber junctures essentially intact, but nylon fibers seen to be degenerated and fragmented.

are quite obvious and need no further comment.

The problem of potential infection persisting around an implanted nonabsorbable material will probably remain no matter how inert the material may be. When it is really necessary to use a prosthesis, the aim should be to keep the amount of added foreign substance to the minimum needed for proper support. Our earlier work with purposely induced infection in animals showed that the open mesh was quite well tolerated and primary healing frequently took place (1). If suppuration occurred, healing usually followed when the area was adequately drained despite the presence of the open mesh. This result was in distinct contrast to a closely woven, less porous, cloth-like fabric which acted as a foreign body fostering continued suppuration until the wound was widely opened and the fabric removed.

Clinically, the incidence of infection has been very low when the mesh was properly employed. The need for a satisfactory covering of skin and subcutaneous tissue in superficially implanted mesh was made apparent in the radical mastectomy patients. In this group, each instance of infection apparently had the common denominator of skin separation due to tension or ischemia which then exposed parts of the underlying mesh.

Chronically draining sinuses did not provide proper drainage. Another factor promoting infection and interfering with proper healing was related to several operators' inexperience with the use of the mesh. This fact resulted in the mesh being loosely placed with redundant free edges protruding too far beyond the anchoring sutures. In 2 patients the infected wound was opened early so as to establish adequate drainage, and healing promptly followed. In these instances the mesh was progressively incorporated in the granulating tissue as the wound closed.

In the postmastectomy infections with chronically draining sinuses, the wounds were opened and the entire mesh deliberately excised. In these cases, loose edges of wrinkled mesh were encountered, but the larger part of the mesh was imbedded in the underlying tissue. After removal of the mesh by traction and sharp dissection, areas of mesh imprint could be seen on the underlying tissue. In retrospect, a number of the chronically draining wounds might have healed with earlier treatment by adequate drainage and excision of any loose redundant areas of mesh.

One other factor deserving mention while discussing wound healing concerns the use of drains. Although all abdominal hernias healed well, it is our impression that a temporary soft rubber Penrose drain would be advantageous in the immediate postoperative period when a large dead space remains after extensive dissection and mesh implantation such as seen following repair of recurring ventral hernias. Occasionally, small catheters with suction drainage may be indicated. Contaminated wounds should also be drained at the time of surgery especially if the surgeon is compelled to use a synthetic prosthesis.

A synthetic pliable mesh is of limited value as a prosthesis to support large defects in the thoracic cage. The pliability of the mesh permits paradoxic movement with larger chest wall defects especially when used in areas where a covering of heavy extracostal muscle is lacking. The special demands imposed by the thorax necessitate the addition of strut-like supports or else the use of a more rigid type of porous prosthesis.

A synthetic mesh may have further applications. In our experience, the mesh has functioned well in covering deficiencies and eventrations of the diaphragm. In fact, it may have practical applications in the repair of certain hiatal hernias when the crura are lax and attenuated. Because the crural muscle is normally devoid of a tough aponeurosis, it is understandable that sutures under tension would cut through the soft crural muscle and allow a patulous hiatus to recur. A supporting sheet of pliable synthetic mesh sutured over the approximated crural limbs and adjacent diaphragm could help reduce the incidence of hernia recurrence.

The mesh may also be used to support the pelvic floor and ptotic structures and organs. Unlike the use of autologous and homologous tissues, there is no need for extra surgery to obtain the synthetic material, nor is it necessary to establish a special tissue bank for storage. Whether synthetic materials left in man may be future sites for infections, tumors, or unforeseen deleterious effects remain to be seen. The final word on the use of pliable, synthetic, knitted mesh must await the tests of numbers and time.

SUMMARY

Clinical and laboratory experiences with pliable synthetic mesh for the support of hernias and tissue defects are reported. A knitted plastic mesh with interlocked fiber junctures functions satisfactorily when properly employed. Certain applications and limitations of this type of prosthesis are discussed.

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# THE RESULTS OF ADEQUATE GASTRECTOMY WITH GASTRODUODENOSTOMY

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IN A PREVIOUS PUBLICATION the senior author (3) concluded: "The technical aspects of adequate gastrectomy with gastroduodenostomy have been presented in some detail. Our experience would indicate that this operation can be done with a low morbidity and mortality. The follow-up results will be analyzed in a subsequent study. We are continuing to perform this operation in accordance with the technical steps described. We hope thereby to have a technically homogenous group of gastrectomies for long term study." In that publication we defined adequate gastrectomy as two-thirds to three-quarters resection and resection of the entire antrum. We wish to present an analysis of the long term results of this surgically homogenous group of adequate resections for ulcer in which the major variable was gastroduodenostomy.

## MATERIAL

In the years 1952 to 1956, 128 resections for ulcer were performed by the technique previously described. In Table I the data are summarized. There were 98 males and 30 females. Seventy-one of the patients were private patients operated on by the senior author and 57 were service patients operated on by a succession of residents. The senior author was present at 25 of these operations. The remaining 27 patients were supervised by other members of the attending staff. There were 53 gastric, 71 duodenal, and 3 marginal ulcers. One patient had a gastroileostomy. No effort was made to select the patients undergoing resection and gastroduodenostomy. The ages varied from 14 to 82 years with a preponderance at 50 to 69 years. Twenty-eight per cent of the patients suffered from significant intercurrent disease, 4 patients were operated upon as emergencies during the course of massive hemorrhage, 32 patients had bleeding sometime in the immediate preoperative period. There was 1 death in the entire group. This patient, with intractable congestive heart failure, died on the second day following emergency resection for massive hemorrhage.

Efforts were made to contact every patient in this series. Doctor William Dwyer, who had no part in the surgery of the patients and who conducted the entire follow-up, succeeded in personally interviewing or obtaining accurate medical information on 116 or 91.4 per cent of the patients. If necessary x-ray or other evaluation studies were performed, the follow-up data are listed in Table II. Ninety-two per cent of the patients

TABLE I.—MATERIAL

| | *No.* | *Per cent* |
|---|---|---|
| Total patients | 128 | |
| Male | 98 | 77 |
| Female | 30 | 13 |
| Private | 71 | 56 |
| Service | 57 | 45 |
| Ulcer type | | |
| Gastric | 53 | 42 |
| Duodenal | 71 | 56 |
| Marginal | 3 | 2 |
| Gastroileostomy | 1 | |
| Age distribution, years | | |
| 14–29 | 4 | 3 |
| 30–49 | 40 | 31 |
| 50–69 | 70 | 55 |
| 70–82 | 14 | 11 |
| History of intercurrent disease (cardiac, pulmonary, diabetes, cancer) | 36 | 28 |
| Massive hemorrhage (emergency surgery—1 death) | 4 | 3 |
| Surgery performed by or supervised by senior author | 96 | 76 |

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TABLE II.—FOLLOW-UP

| | *No.* | *Per cent* |
|---|---|---|
| Follow-up time, months | | |
| 49–60 | 10 | 8 |
| 37–48 | 36 | 28 |
| 25–36 | 35 | 27 |
| 13–24 | 24 | 19 |
| 12 or less | 10 | 8 |
| Operative death | 1 | 0.8 |
| Total patients followed | 116 | 91 |
| Lost to follow-up | 12 | 9 |
| Service cases lost | 9 | 16* |
| Private cases lost | 3 | 5† |
| Deaths | | |
| Operative | 1 | 0.8 |
| Follow-up, 16–35 months (none related to ulcer or surgery) | 7 | 6 |

*Per cent of service cases.
†Per cent of private cases.

TABLE III.—DUMPING SYNDROME

| | *No.* | *Per cent* |
|---|---|---|
| No dumping | 54 | 54 |
| Mild dumping | 35 | 35 |
| Moderate or severe dumping | 11 | 11 |
| Data available | 100 | |
| No data available | 20 | |
| Anastomotic ulcers excluded | 8 | |
| Total | 128 | |

had undergone the operation more than 12 months before the time of follow-up. Sixty-three per cent of the patients were 25 or more months postoperative and 36 per cent of the patients were 36 to 60 months postoperative.

Seven patients died in the follow-up period, 16 to 35 months after surgery. Accurate data were obtained on all of these patients, 4 died of cardiovascular disease, 1 of pulmonary tuberculosis, 1 of nasopharyngeal squamous cell carcinoma, and 1 of a hypernephroma. None of this group manifested evidence of recurrent ulcer disease.

TABLE IV.—RESULTS: RECURRENT—ANASTOMOTIC ULCER

| | *No.* | *Per cent* |
|---|---|---|
| Recurrent—anastomotic ulcers | 8 | 6 |
| Recurrence in patient with resection for gastric ulcer | 0 | 0 |
| Recurrence in patients with resection for duodenal ulcer | 8 | 11 |
| Recurrence in private patients with duodenal ulcer | 6 | 14 |
| Treatment | | |
| Responded to medical treatment | 3 | |
| Treated by vagotomy | 1 | |
| Gastroduodenostomy taken down, duodenal stump closed, gastrojejunostomy performed (no vagotomy) | 4 | |

## RESULTS

The evaluation of the patients is divided into three categories, nutritional, dumping, and recurrent ulcer. The nutritional status of some patients following conventional gastrectomy and gastrojejunostomy is impaired. This fact has been manifested by a failure to gain or maintain weight postoperatively. The proponents of gastrectomy and gastroduodenostomy contend that nutritional problems are improved by the Billroth I type of operation. Indeed, there are reports in the literature suggesting that serious nutritional disturbances following the Billroth II type of gastrectomy could be corrected by converting the operation to a Billroth I.

The nutritional results in our cases fell short of expectation. In Figure 1 the postoperative weight is compared with the preoperative weight. Forty-eight per cent of the patients failed to regain their preoperative weight, this, notwithstanding the fact that in some instances the preoperative weight was less than normal. In Figure 2 where postoperative weight is compared to usual weight, 60 per cent of the patients failed to reach their usual weight. All of those patients with intercurrent disease capable of adversely affecting weight have been excluded from the analysis.

The data on the dumping syndrome are summarized in Table III. What constitutes mild, moderate, or severe dumping is largely a subjective evaluation on the part of the interviewer. In this series the interviewer had no part in the surgery and we hope therefore that his conclusions were as objective as possible. Symptoms of dumping in the period 4 to 6 weeks after operation were disregarded. It has been our experience that immediately following major abdominal surgery not on the stomach many patients will admit to symptoms of dumping.

All patients who had the slightest evidence of fullness, palpitation, nausea, or cold sweats immediately after eating were categorized as mild. This group was further designated to patients whose symptoms were not incapacitating, who did not have to lie flat to obtain

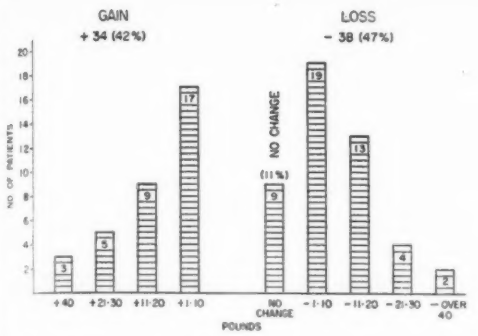


FIG. 1. Comparison of preoperative and postoperative weight. Reliable data obtained on 81 patients without intercurrent disease.

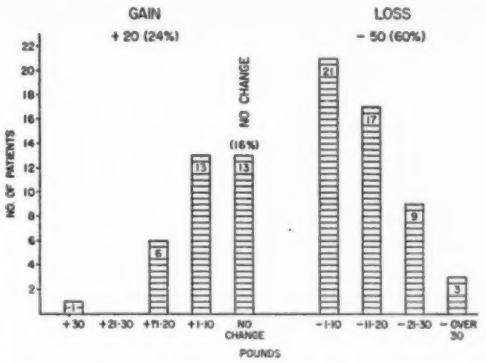


FIG. 2. Comparison of usual weight and postoperative weight. Reliable data obtained on 83 patients without intercurrent disease.

relief, and who sought or took no medication for relief. Thirty-five patients, or 35 per cent of those on whom reliable data were obtained, fell into this mild category.

Patients who had some distress or any of the symptoms mentioned every day and who were occasionally forced to lie down for relief were considered in the moderate category. The patient who had distress after practically every meal, and who had to lie down at least once a day, who was disabled, and feared eating was considered in the severe group. By these arbitrary criteria 11 per cent of the patients fell into the moderate dumping group. There were no patients in the severe dumping group. Some form of dumping was present in 46 per cent of the 100 patients in whom reliable data were available. The recurrent ulcers were excluded from the group.

Recurrent anastomotic ulcer is the hallmark of unquestioned failure of ulcer surgery. Up to the time of follow-up, 8 patients or 6 per cent of our entire series had proved recurrent ulcers either at or near the gastroduodenostomy. All of these occurred in patients who had had a resection for duodenal ulcer. The recurrence rate in this group was 11 per cent. In the senior author's private group of duodenal ulcer resections the recurrence rate was 14 per cent. No patient who had a resection for gastric ulcer has thus far manifested a recurrent ulcer. Three patients with recurrent ulcers proved by x-ray examination have responded to medical management. Five patients have been reoperated upon, and the ulcer proved at surgery. One patient had a vagotomy, and 4 patients had the gastroduodenostomy taken down, the duodenal stump closed, and a gastrojejunostomy performed to the gastric stump resected only immediately beyond the suture line. All patients continue to do well.

## DISCUSSION

Two-thirds to three-quarters resection of the stomach with gastroduodenostomy as performed by us, although a safe procedure from morbidity and mortality aspects, has

TABLE V.—RESULTS: COMPARATIVE SERIES

| *Authors* | *Per cent follow-up* | *Resection for gastric ulcer* | *Per cent recurrence gastric ulcer group* | *Resection for duodenal or marginal ulcer* | *Per cent recurrence duodenal or marginal ulcer group* |
|---|---|---|---|---|---|
| Hickinbotham | 94 | 132 | 0.8 (1) | 100 | 10 (10) |
| Harkins *et al.* (2) | 95 | 451 (total) | 0.2 (1) | 451 (total) | 1.1 (4) |
| Ordahl *et al.* | 83 | 22 | 4.5 (1) | 35 | 28.6 (10) |
| Wallensten | — | 33 | 6.1 (2) | 111 | 11.7 (13) |
| Walters *et al.* | — | 113 | 4.4 (5) | 53 | 13.2 (9) |
| Localio and Dwyer | 91 | 53 | 0 | 75 | 10.6 (8) |

fallen far short of expectation. Nutritional problems as measured by inability to gain weight have been present in some degree in 48 to 60 per cent of the patients. The dumping syndrome although only mild and moderate has occurred in 46 per cent of the patients. It was hoped that gastroduodenostomy would be associated with fewer of these nutritional and dumping sequelae. Finally, gastroduodenostomy has failed in spite of adequate gastrectomy in the patient with resection for duodenal ulcer. Certainly 11 per cent recurrence, a rate that may increase as the follow-up is longer, is far more than obtained by conventional surgery. Table V compares our series with other published data. With the exception of Harkins and associates the recurrence rate in the duodenal ulcer group is disturbingly high. On the other hand in the gastric ulcer resections our recurrence rate was 0 and that in the comparative series is considerably lower than the duodenal ulcer group.

## CONCLUSIONS

1. Two-thirds to three-quarters gastrectomy with gastroduodenostomy has been found to be associated with a significant percentage of postoperative nutritional and dumping problems.

2. The operation in spite of "anatomical adequacy" is a failure in patients with duodenal ulcer because of the high rate of recurrent ulcer.

3. The operation, up to follow-up reported, is not associated with recurrent ulcer in the gastric ulcer group, and continued clinical trial of the procedure for gastric ulcer is justified.

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# AN EVALUATION OF VARIOUS CARDIOPLEGIC METHODS UTILIZING ISOLATED PERFUSED GUINEA PIG HEARTS

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SINCE ITS ORIGINATION by Melrose, elective cardiac arrest has achieved a recognized place in open heart surgery. Some of the reasons advanced for this procedure are that the danger of air embolism is lessened, a motionless, almost bloodless field is provided with excellent visibility, blood loss is decreased, and, since the entire coronary circulation is stopped, there need be no fear of kinking or obstructing the coronary vessels. Open operations on the aortic valve would be impossible without stopping the heart unless the coronary arteries were separately perfused. Methods permitting arrest and ready reinstitution of the heart action should serve to extend further the scope of operative procedures that can be performed utilizing extracorporeal circulation techniques.

Successful elective cardiac arrest and recovery in isolated animal hearts, in intact animals, and in human surgery have been accomplished by Melrose and Effler using potassium citrate, Moulder and associates with acetylcholine; Young, Sealy, and associates utilizing potassium citrate and magnesium sulfate in combination; and Lam by injecting potassium chloride.

In a recent article Merritt and Sealy indicated that a combination of potassium, neostigmine, and magnesium is superior to potassium citrate alone. They state that although cardioplegia is immediate following the use of either of these methods, there is more rapid recovery on reperfusion following the use of the combined materials. Following the injection of potassium citrate alone, the heart required about 3 minutes of perfusion to return to a normal beat.

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Anoxia and profound hypothermia have also been observed to cause cardiac arrest, as has A.C.D. solution.[1]

The work herein reported was done to evaluate the effects of various cardioplegic agents on the isolated, perfused guinea pig heart. The actions of potassium citrate, acetylcholine, potassium citrate plus magnesium sulfate, A.C.D. solution, anoxia, and profound hypothermia were investigated and compared.

## MATERIALS AND METHODS

Healthy, adult guinea pigs of either sex weighing from 500 to 800 grams were anesthetized with 30 milligrams per kilogram of sodium pentobarbital intraperitoneally. In most cases, a small amount of ether was required as a supplement. A tracheal cannula was inserted, artificial respiration instituted, and the chest opened. Heparin, 5 milligrams per kilogram, was injected into the inferior vena cava to prevent clotting. The pericardium was opened and the ascending aorta stripped of surrounding tissue and mobilized. A loop of heavy thread was placed around the aorta close to its origin and a second loop of No. 000 silk placed a few millimeters higher. The proximal loop of thread was then tightened, the aorta incised, and a glass cannula inserted into it. The tightening of the loop of thread prevented the cannula from passing through and damaging the aortic valves. After the distal thread was tied securing the cannula in place, the proximal loop was loosened. The great vessels were then severed and the heart was removed from the chest. The glass cannula was inserted into the per-

[1]A.C.D. solution, "Formula B," U.S.P. and N.I.H. Dextrose 1.47 grams, sodium citrate 1.32 grams, citric acid 0.44 gram per 100 cubic centimeters.

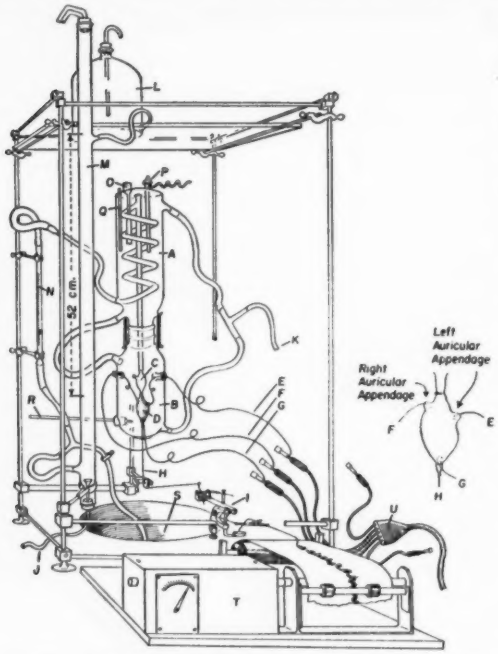


FIG. 1. The isolated perfused heart apparatus: *A*, constant temperature bath surrounding the warming spiral; *B*, double walled glass heart chamber; *C*, glass cannula; *D*, heart; *E*, *F*, *G*, electrodes placed as indicated in enlargement at right; *H*, loop of thread through apex of heart passed through an opening in outer glass chamber, around a pulley wheel and attached to writing lever *I*; *J*, inlet tube for 95 per cent oxygen and 5 per cent carbon dioxide; *K*, tube for attachment to compressed air to keep water circulating in constant temperature bath and double walled glass chamber; *L*, Mariotte bottle; *M*, oxygenator tube; *N*, flow meter; *O*, heating element with thermostat, *P*; *Q*, thermometer in water bath; *R*, thermometer through double walled glass chamber; *S*, funnel to catch and drain off the perfusion fluid flowing out of the heart; *T*, variable speed motor for turning recording paper on drum; *U*, electrocardiographic connector to electroencephalograph.

fusion apparatus and perfused according to the method of Langendorff as modified by Garb. The heart was subjected to a minimal period of hypoxia seldom exceeding 45 seconds from the time of removal to onset of perfusion. Hearts were perfused with Ringer-Locke solutions composed of: sodium chloride 7 grams per liter, potassium chloride 0.42 gram per liter, calcium chloride 0.24 gram per liter, magnesium chloride 0.2 gram per liter, or magnesium chloride hexahydrate 0.48 gram per liter. The perfusate was not recirculated. The perfusion fluid flowed downward through a tube 1 meter long interposed between a Mariotte bottle containing the Ringer-Locke solution and the warming spiral, while a gas mixture of 95 per cent oxygen and 5 per cent carbon dioxide in the form of tiny bubbles rose from a sintered glass disc at the bottom of the tube. Thorough oxygenation of the perfusion fluid proved essential for a well functioning preparation. In all experiments, perfusion pressure was 52 centimeters of water. A double walled glass chamber fitting about the heart was heated by several large light bulbs placed nearby. Temperature in the bath about the warming spiral was maintained by means of an electric heater controlled thermostatically. Simultaneous recordings of temperature of the bath and the chamber were taken.

A small loop of thread was passed through the apex of the heart, through an opening in the outer glass chamber, around a small pulley, and attached to a writing lever. Contractile force and heart rate could thus be measured directly from the tracings (Fig. 1).

After the heart had assumed a regular rate and rhythm and had reached maximum amplitude of contraction, the cardioplegic agents to be investigated were injected in such a way as to perfuse the coronary arteries. At the same time that the agent was injected, the perfusion fluid was stopped. After the desired period of arrest, the perfusion was resumed and allowed to continue until maximum recovery was achieved before additional tests were made. The order in which drugs were used was varied with each heart. All compounds were tested on at least 4 different hearts. With the exception of the hypothermic studies, all perfusions were done at a temperature of 38 degrees C.

Hypothermic conditions were achieved by using a refrigerant circulating about the perfusion spiral and through the double walled glass chamber. In these tests the perfusion fluid was not interrupted during the cooling or reheating period.

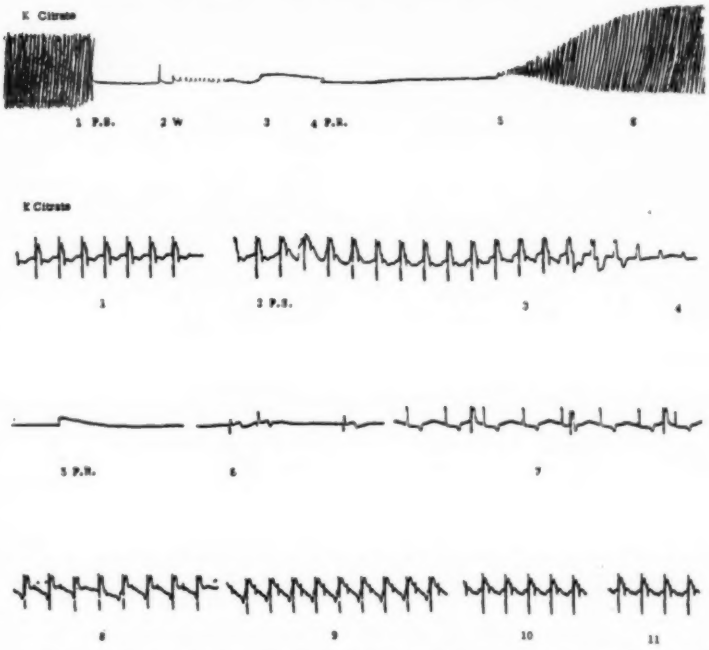


FIG. 2. Tracing of mechanical activity on upper line: *1 P.S.*, perfusion stopped and 1 cubic centimeter of 1.25 per cent potassium citrate injected followed by immediate arrest; *2 W*, solution washed through tubing with 0.6 cubic centimeter of Ringer's solution causing a few beats; *3*, return to mechanical arrest; *4 P.R.*, perfusion restarted after 60 minute arrest; *5*, onset of mechanical activity 45 seconds after perfusion restarted; *6*, return to maximum amplitude 90 seconds after reperfusion. Electrocardiographic tracings: *1*, control; *2 P.S.*, perfusion stopped and injection of 1 cubic centimeter of 1.25 per cent potassium citrate begun; *3*, injection completed; *4*, decreasing electrical activity which persisted for 2 seconds after mechanical arrest; *5 P.R.*, perfusion restarted after 10 minute arrest; *6*, onset of electrical activity 20 seconds after reperfusion; *7*, 1 minute; *8*, 2 minutes; *9*, 3½ minutes; *10*, 5 minutes; *11*, 8 minutes after perfusion reinstituted.

In the anoxic studies, the perfusion was stopped until mechanical arrest occurred.

The electrocardiograph was recorded by using 3 stainless steel wires as electrodes. Two of them, hook-shaped at the ends, were fixed to the right and left auricular appendix. The third one was placed through the apex of the heart. Lead II was recorded.

The materials used were obtained from commercial sources and consisted of (1) 1.25 per cent potassium citrate, given in 1 cubic centimeter amounts; (2) Sealy's mixture ($K_3C_6H_5O_7 \cdot H_2O$ 0.54 gm. and $MgSO_4 \cdot 7\,H_2O$ 2.7 gm. per 100 c.c. $H_2O$) brought to *p*H 7.4 with sodium bicarbonate, given in 2 cubic centimeter doses; (3) acetylcholine 2 cubic centimeters of 5 milligrams per cubic centimeter; (4) A.C.D. solution 5 cubic centimeters of 1:2 dilution of stock solution. All injections were made rapidly.

## RESULTS (TABLES I AND II)

*Potassium citrate.* In 12 determinations using 1 cubic centimeter of 1.25 per cent potassium citrate injected into the coronary artery perfusion tubing, arrest was immediate. The average time for initial recovery was 43 seconds. Maximum recovery occurred on the average in 2 minutes 48 seconds. The average initial heart rate was 187 beats per

TABLE I.—MECHANICAL ACTIVITY

| Agent | Initial (average): No. of determinations | Initial (average): Amplitude, cms. | Initial (average): Rate per min. | Time to arrest* | Duration of arrest | Time to recovery: Initial, min. | Time to recovery: Initial, sec. | Time to recovery: Maximum, min. | Time to recovery: Maximum, sec. | Maximum recovery: Amplitude, per cent of initial | Maximum recovery: Rate per min. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K citrate | 12 | 1.9 | 187 | Immediate | 22 min. | 0 | 43 | 2 | 48 | 104.8 | 187 |
| Sealy's mixture | 10 | 1.6 | 198 | Immediate | 19 min. 5 sec. | 1 | 04 | 3 | 18 | 90.4 | 194 |
| Acetylcholine | 13 | 1.6 | 178 | 0.1 sec. | 11 min. 8 sec. | 0 | 22 | 5 | 10 | 93.2 | 174 |
| A.C.D. solution | 15 | 2.6 | 183 | 0.2 sec. | 26 min. | 1 | 31 | 3 | 16 | 87.1 | 196 |
| Anoxia | 10 | 2.0 | 192 | 5 min. 8 sec. | 22 min. 1 sec. | 0 | 47 | 5 | 51 | 82.4 | 205 |
| Hypothermia | 4 | 1.8 | 195 | Temp. 16.2° C. | 10 min. | Temp. 25.5°C. | | Temp. 38°C. | | 78.2 | 176 |

*All times listed are averages.

TABLE II.—ELECTRICAL ACTIVITY

| Agent | No. of determinations | Time to arrest* | Duration of arrest | Time to initial recovery | Time taken to return to regular rhythm | Remarks |
|---|---|---|---|---|---|---|
| K citrate | 7 | 4 sec. | 14 min. 20 sec. | 24 sec. | 1 min. 30 sec. | Although a regular rhythm occurred within 1½ min., control EKG pattern occurred on the average of 3 minutes after reperfusion was started |
| Sealy's mixture | 7 | 6 sec. | 12 min. 18 sec. | 45 sec. | 1 min. 46 sec. | Although a regular rhythm occurred within 1 min. 46 sec., control type of EKG pattern did not occur until average of 5 min. after reperfusion began |
| Acetylcholine | 7 | 4 sec. | 13 min. 24 sec. | 20 sec. | 1 min. 40 sec. | Although a regular rhythm occurred within 1 min. 40 sec., control type of EKG pattern did not occur until average of 5 min. after reperfusion began |
| A.C.D. solution | 4 | 10 sec. | 16 min. | 35 sec. | 2 min. 30 sec. | Although a regular rhythm occurred within 2 min. 30 sec., a control type of EKG pattern did not occur until average of 6 min. after reperfusion began |
| Anoxia | 4 | No electrical arrest attained to 70 min. | (Mechanical) 37 min. 30 sec. | | 4 min. | Upon oxygenation fibrillation began and persisted for 1-2 min. after which regular rhythm began. Control type of EKG pattern on average of 5 min. after reperfusion began |
| Hypothermia | 2 | Temp. 16.2° C. | 10 min. | Temp. 23°C. | Temp. 38°C. | Regular EKG pattern began at temp. 30 C. and continued unchanged except for increase in rate until normal temp. reached |

*All times listed are averages.

minute with an average amplitude of contraction of 1.9 centimeters. At the time of maximum recovery the average rate returned to 187 beats per minute. The average amplitude of contraction rose to 1.99 centimeters, slightly above the initial levels (Fig. 2). The periods of arrest varied from 5 minutes to 1 hour with an average time of 22 minutes. In 1 case (determination 13) a heart did not recover after 60 minutes of arrest. This preparation had undergone a 60 minute period of anoxic arrest 30 minutes earlier.

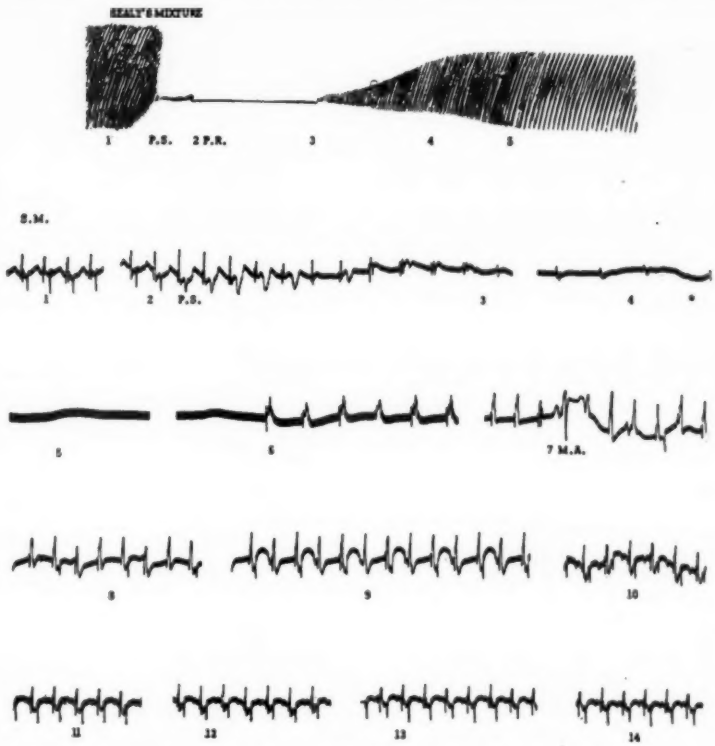


FIG. 3. Tracing of mechanical activity on upper line: *1*, control amplitude of contraction; *P.S.*, perfusion stopped and 2 cubic centimeters of Sealy's mixture injected followed by immediate arrest; *2 P.R.*, perfusion restarted after 30 minute arrest; *3*, onset of mechanical activity 30 seconds after reperfusion; *4*, amplitude of contraction increasing; *5*, maximum amplitude of contraction 100 seconds after restarting perfusion. At extreme right the tracing is at a higher speed of drum rotation to show the shape of the contraction wave. Electrocardiographic tracings: *1*, control; *2 P.S.*, perfusion stopped and injection of 2 cubic centimeters of Sealy's mixture begun; *3*, injection completed; *4*, decreasing electrical activity with arrest (indicated by asterisk) 4 seconds after injection ended; *5*, perfusion restarted after 10 minute arrest; *6*, onset of electrical activity 40 seconds after reperfusion; *7 M.A.*, mechanical activity began at this point 58 seconds after perfusion restarted; *8*, 2 minutes; *9*, 3 minutes; *10*, 5 minutes; *11*, 8 minutes; *12*, 10 minutes; *13*, 13½ minutes; *14*, 14 minutes after reperfusion.

Electrocardiographic determinations (Table II) done on 7 hearts arrested for an average of 14 minutes and 20 seconds each revealed that electrical activity persisted for 2 to 7 seconds, average 4 seconds, following mechanical arrest. Initial electrocardiographic recovery occurred on the average in 24 seconds with return to a regular rhythm in 1 minute 30 seconds (Fig. 2).

*Sealy's mixture (potassium citrate and magnesium sulfate)*. A total of 10 determinations were done by injecting 2 cubic centimeters of this mixture into the coronary arteries through the perfusion tubing. Mechanical arrest was immediate in all instances. Initial recovery occurred on the average in 1 minute 4 seconds while maximum recovery averaged 3 minutes 18 seconds. The average initial heart rate was 198 beats per minute with an average amplitude of 1.6 centimeters. At the

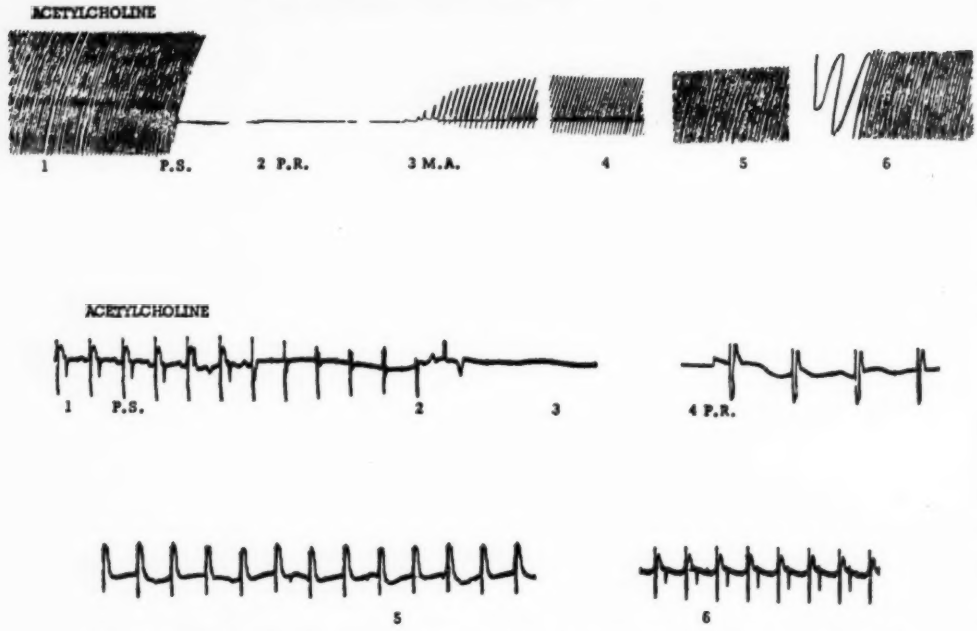


FIG. 4. Tracing of mechanical activity on upper line: *1*, control amplitude of contraction; *P.S.*, perfusion stopped 1.2 cubic centimeters of acetylcholine solution, 5 milligrams per cubic centimeter, injected followed by immediate arrest; *2 P.R.*, perfusion restarted after 30 minute arrest; *3 M.A.*, onset of mechanical activity 50 seconds after reperfusion; *4*, 2 minutes; *5*, 3½ minutes; *6*, 4 minutes after perfusion restarted. Electrocardiographic tracings: *1*, control; *P.S.*, perfusion stopped and injection of 2 cubic centimeters of acetylcholine chloride solution, 5 milligrams per cubic centimeter, begun; *2*, injection completed; *3*, arrest 1 second after injection; *4*, perfusion restarted after 10 minute arrest with rapid onset of electrical activity; *5*, 3 minutes; *6*, 11 minutes after reperfusion.

time of maximum recovery the average rate was 194 beats per minute. The average amplitude of contraction returned to 1.45 centimeters, 90.4 per cent of the initial value (Fig. 3). The periods of arrest varied from 9 to 30 minutes for an average of 19 minutes and 5 seconds.

Electrocardiographic determinations done on 7 hearts arrested for an average of 12 minutes and 18 seconds each revealed that electrical activity persisted for an average of 6 seconds after mechanical activity had ceased. Initial electrocardiographic recovery occurred on the average in 45 seconds with return to a regular rhythm in 1 minute and 46 seconds (Fig. 3).

*Acetylcholine.* In 13 determinations using 2 cubic centimeters of a 5 milligrams per cubic centimeter solution, mechanical arrest was immediate in 10 instances, took 0.8 second in 1 case, 1.0 second in another, and 0.6 second in a third for an average time to arrest of 0.1 second. Initial recovery occurred on the average in 22 seconds while the maximum recovery time averaged 5 minutes 10 seconds. The initial heart rate averaged 178 beats per minute with an average amplitude of contraction of 1.6 centimeters. At the time of maximum recovery the average rate was 174 beats per minute. The average amplitude of contraction returned to 1.49 centimeters, 93.2 per cent of the initial value (Fig. 4). The periods of arrest varied from 5 to 30 minutes for an average of 11 minutes 8 seconds.

Electrocardiographic determinations done on 7 hearts arrested for an average of 13 minutes and 24 seconds each revealed that

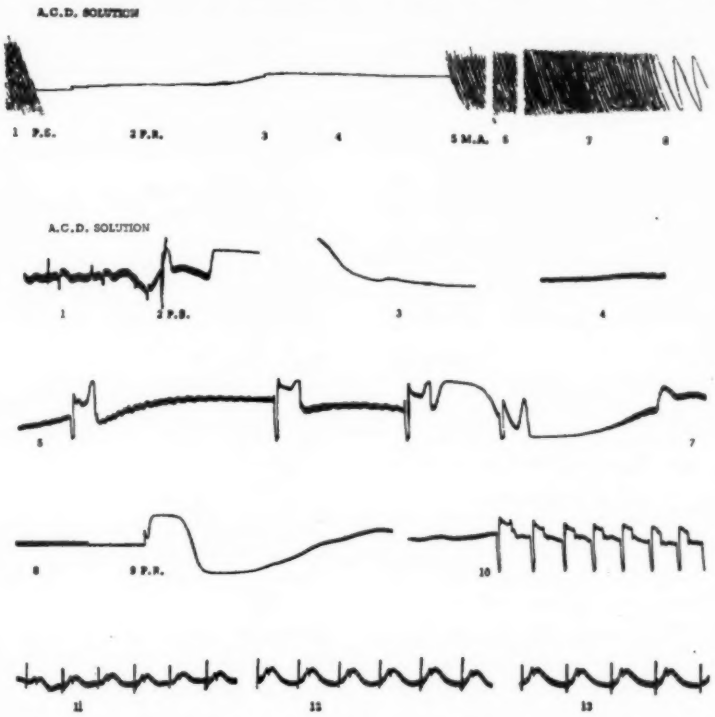


FIG. 5. Tracing of mechanical activity on upper line: *1*, control amplitude of contraction; *P.S.*, perfusion stopped 6 cubic centimeters of A.C.D. solution, 1:2 dilution of stock solution, injected followed by arrest; *2 P.R.*, perfusion restarted after 30 minute arrest; *3*, 35 seconds; *4*, 50 seconds after reperfusion; *5 M.A.*, onset of mechanical activity 1 minute 15 seconds after perfusion restarted; *6*, 1 minute 25 seconds; *7*, 2 minutes 15 seconds after reperfusion with return to maximum amplitude; *8*, 2 minutes 30 seconds after perfusion restarted with tracing at a higher speed of drum rotation to show the shape of the contraction wave. Electrocardiographic tracings: *1*, control; *2 P.S.*, 6 cubic centimeters of A.C.D. solution, 1:2 dilution of stock solution, injection begun; *3*, *4*, during injection; *5*, injection completed; *7*, arrest 7½ seconds after injection; *8*, tracing of arrest; *9 P.R.*, perfusion restarted after 10 minute arrest; *10*, onset of electrical activity 36 seconds after start of reperfusion; *11*, 4 minutes 15 seconds; *12*, 6 minutes; *13*, 8 minutes after perfusion restarted.

electrical activity persisted for 4 seconds after mechanical activity had ceased. Initial electrocardiographic recovery occurred on the average in 20 seconds with return to a regular rhythm in 1 minute and 40 seconds (Fig. 4).

*A.C.D. (sodium citrate, citric acid, dextrose) solution.* In 15 determinations using 5 cubic centimeters of a 1:2 dilution of this stock solution, mechanical arrest was immediate in 11 instances, took 1.5 seconds in 1 and 0.5 second in 3 others for an average time to arrest of 0.2 second. Initial recovery occurred on the average of 1 minute 31 seconds while maximum recovery required an average of 3 minutes 16 seconds. The initial heart rate averaged 183 beats per minute with an average amplitude of contraction of 2.6 centimeters. At the time of maximum recovery the rate averaged 196 beats per minute. The amplitude returned to an average of 2.26 centimeters, 87.1 per cent of the

initial value (Fig. 5). The periods of arrest varied from 5 to 63 minutes for an average of 26 minutes.

Electrocardiographic determinations done on 4 hearts arrested for an average of 16 minutes each revealed that electrical activity persisted for an average of 10 seconds after mechanical activity had ceased. Initial electrocardiographic recovery occurred on the average in 35 seconds with return to a regular rhythm in 2 minutes 30 seconds (Fig. 5).

*Anoxia.* In 10 determinations the amplitude of contraction and the heart rate gradually decreased after the flow of perfusion fluid was stopped. Mechanical arrest occurred from 3 minutes 34 seconds to 10 minutes after the clamp was applied for an average time to arrest of 5 minutes 8 seconds. Initial recovery occurred in 47 seconds on the average while maximum recovery required 5 minutes 51 seconds. The initial heart rate averaged 192 beats per minute with an average amplitude of contraction of 2.0 centimeters. At the time of maximum recovery the average rate was 205 beats per minute. The average amplitude of contraction returned to 1.65 centimeters, 82.4 per cent of the initial value (Fig. 6). The periods of arrest varied from 10 to 60 minutes for an average of 22 minutes 1 second. In 1 instance (determination 11) a heart did not recover following 70 minutes of arrest. This preparation had undergone a 60 minute period of potassium citrate arrest 30 minutes earlier.

Electrocardiographic determinations done on 4 hearts arrested for an average of 37 minutes and 30 seconds each revealed that electrical activity persisted long after mechanical activity had ceased. In 1 heart with mechanical arrest for 70 minutes there was electrical activity throughout the period of arrest. At the end of this time, the rate was 36 beats per minute and consisted only of a ventricular complex. When perfusion was restarted fibrillation, both ventricular and auricular, occurred. The heart never recovered a normal electrocardiographic pattern nor did mechanical activity recur. All the hearts showed some degree of fibrillation after removal of the clamp and reperfusion. In some cases this was marked. Return to a regular rhythm occurred on the average in 4 minutes (Fig. 6).

*Hypothermia.* In 4 determinations using a circulating refrigerant to cool the perfusion bath and the heart chamber, arrest occurred at temperatures of 15.0 to 17.0 degrees C., an average of 16.2 degrees C. Initial recovery after reheating occurred with temperature of perfusion bath at 22 to 26 degrees C., an average of 25.5 degrees C. After initial recovery, there was a gradual increase in amplitude of contraction and heart rate which continued until maximum recovery occurred, usually at the original starting temperature of the perfusion bath, 38 degrees C. The initial heart rate averaged 195 beats per minute with an average amplitude of contraction of 1.8 centimeters. At the time of maximum recovery the rate averaged 176 beats per minute. The amplitude of contraction returned to an average of 1.41 centimeters, 78.2 per cent of the initial value (Fig. 7a). The periods of arrest were 10 minutes. Electrocardiographic determinations on 2 hearts arrested for 10 minutes each revealed that electrical activity ceased at the same time that mechanical activity stopped. Initial electrocardiographic recovery after reheating occurred at average bath temperature of 23 degrees C. Regular electrocardiographic pattern began at an average of 30 degrees C. and continued unchanged except for increase in rate until normal (starting) temperatures had been reached (Fig. 7b).

## DISCUSSION

Each of the methods or chemicals tested was capable of producing elective cardiac arrest. Potassium citrate and Sealy's mixture caused immediate mechanical arrest, while acetylcholine required 0.1 second and A.C.D. solution 0.2 second. A period of anoxia averaging 5 minutes 8 seconds was necessary for cardioplegia with this technique. Mechanical recovery as measured by the amplitude of

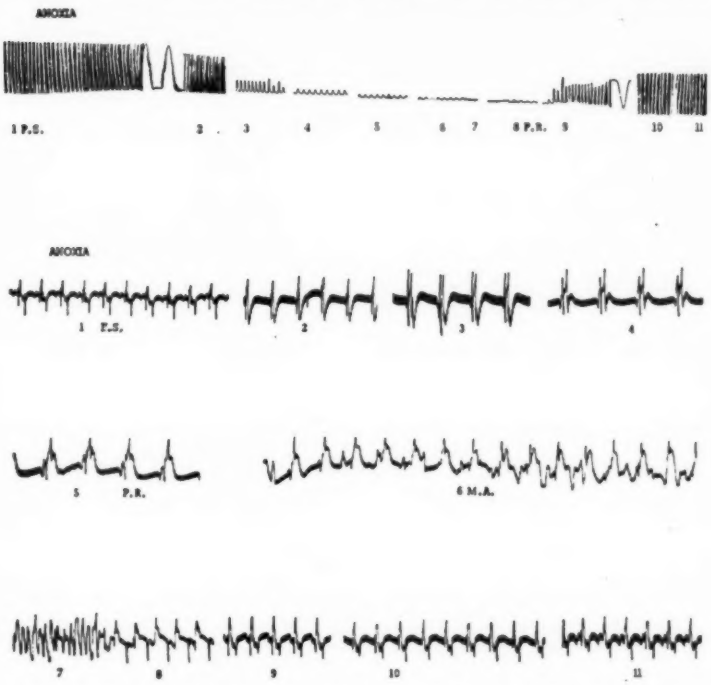


FIG. 6. Tracing of mechanical activity on upper line: *1*, control amplitude of contraction; *P.S.*, perfusion stopped; *2*, 1 minute; *3*, 3 minutes; *4*, 4 minutes; *5*, 5 minutes; *6*, 6 minutes after perfusion stopped; *7*, mechanical arrest; *8 P.R.*, perfusion restarted after 30 minute arrest; *9*, 30 seconds; *10*, 1 minute; *11*, 5 minutes after perfusion restarted with return to maximum amplitude. Electrocardiographic tracings; *1*, control; *P.S.*, perfusion stopped; *2*, mechanical arrest occurred here at 3 minutes 15 seconds after cessation of perfusion; *3*, 9 minutes; *4*, 16 minutes; *5*, 19 minutes after perfusion stopped (15 minutes 45 seconds after mechanical arrest); *6 M.A.*, mechanical activity occurred at this point, 20 seconds after reperfusion; *7*, fibrillation about 1 minute 30 seconds after perfusion restarted; *8*, regular pattern following fibrillation; *9*, 5 minutes; *10*, 9 minutes; *11*, 15 minutes after reperfusion.

contraction, following potassium citrate arrest was 100 per cent. Subsequent to acetylcholine and Sealy's mixture, the perfused hearts recovered to 93 and 90 per cent of initial amplitude. After use of A.C.D. solution recovery was 87 per cent. Anoxia and hypothermia arrests were followed by 82 and 78 per cent return to initial amplitude of contraction.

Electrocardiographic activity persisted for several seconds after mechanical arrest in all instances. Although mechanical arrest occurred in anoxia, electrical arrest did not occur for as long as 70 minutes following cessation of all contractions. It would seem that electrical activity in anoxia continues until true death of the heart. With all methods, initial recovery is associated with some electrocardiographic irregularities. Initial electrical recovery occurred earliest after the use of acetylcholine and latest after Sealy's mixture. Return to normal or control type of electrocardiogram was seen first after potassium citrate arrest and last after A.C.D. solution. The electrocardiogram after anoxic arrest showed marked fibrillation that lasted several minutes before the normal or control electrocardiogram recurred.

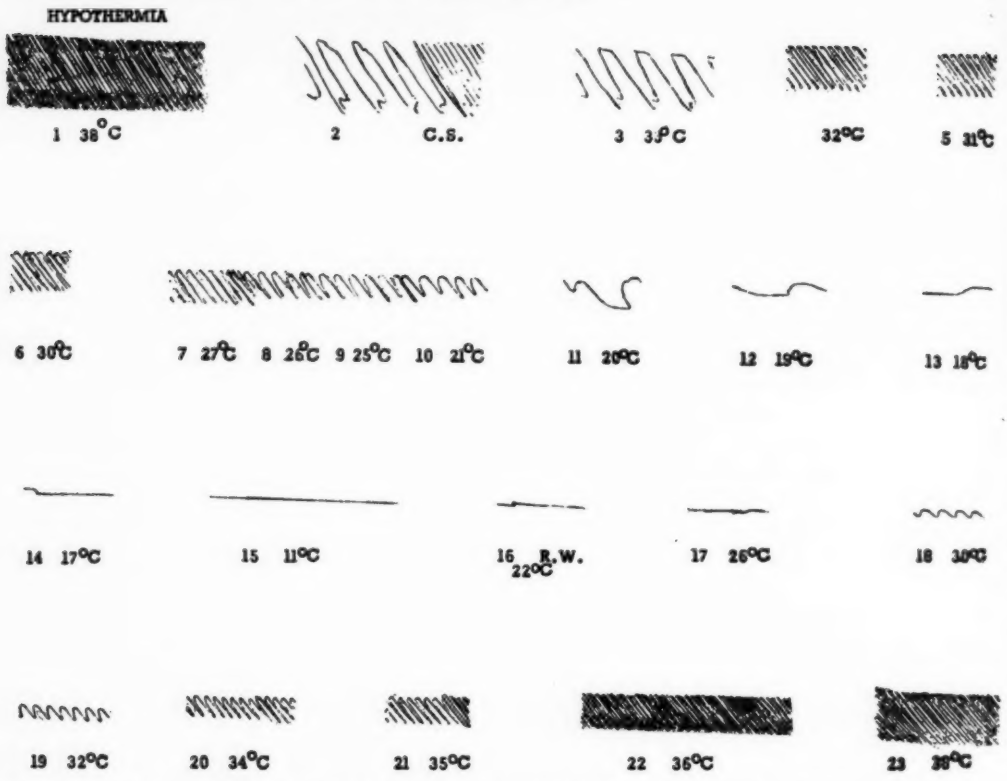


FIG. 7. a, Tracing of mechanical activity: *1*, control amplitude of contraction, temperature 38 degrees C., *2*, *C.S.*, cooling started; *3*, 33 degrees C.; *4*, 32 degrees C.; *5*, 31 degrees C.; *6*, 30 degrees C.; *7*, 27 degrees C.; *8*, 26 degrees C.; *9*, 25 degrees C.; *10*, 21 degrees C.; *11*, 20 degrees C.; *12*, 19 degrees C.; *13*, 18 degrees C.; *14*, 17 degrees C. mechanical activity has ceased; *15*, 11 degrees C. arrest continues; *16*, rewarming has begun after 10 minute arrest at 22 degrees C.; *17*, 26 degrees C. there is some mechanical activity; *18*, 30 degrees C.; *19*, 32 degrees C.; *20*, 34 degrees C.; *21*, 35 degrees C. (tracings from *2* to *21* were taken at drum speed setting of 5 seconds per rotation); *22*, 36 degrees C., with drum rotation setting the same as control tracing; *23*, 38 degrees C. return to maximum amplitude of contraction.

Initial electrocardiographic recovery following hypothermia occurred at a temperature of 23 degrees C. At this time the electrocardiogram showed primarily a poorly defined slow ventricular complex. However, as the temperature rose, the pattern became more normal and was like that of the control when the temperature reached 30 degrees C. Further increase in temperature caused an increase in rate to control ranges without changes in pattern.

The mechanism of arrest by these various agents is not known. It is tempting to explain all of the effects on the basis of accumulation of potassium on the outside of the cell membrane. Such a concept would postulate endogenous and exogenous sources of potassium as the causative agents of arrest. Thus, using potassium citrate or Sealy's mixture, a high extracellular potassium concentration is achieved by the perfusion of the coronary arteries with these potassium rich solutions. In the case of A.C.D. solution, the citrate probably acts on the available extracellular calcium to change the calcium potassium ratio, in essence increasing potassium

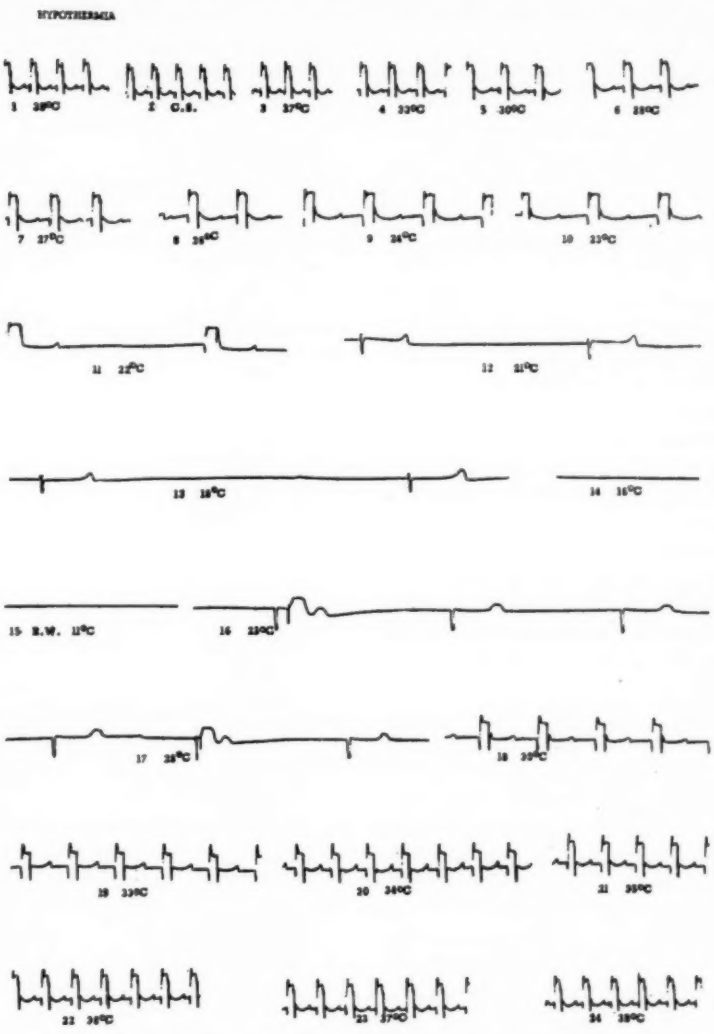


FIG. 7. b, Electrocardiographic tracings: *1*, control at temperature 38 degrees C.; *2 C.S.*, cooling started; *3*, 37 degrees C.; *4*, 33 degrees C., rate is decreasing; *5*, 30 degrees C.; *6*, 28 degrees C.; *7*, 27 degrees C.; *8*, 26 degrees C.; *9*, 24 degrees C.; *10*, 23 degrees C.; *11*, 22 degrees C. marked bradycardia; *12*, 21 degrees C.; *13*, 18 degrees C.; *14*, 16 degrees C., electrical activity has ceased; *15 R.W.*, 11 degrees C., arrest continues, rewarming started; *16*, 23 degrees C., onset of electrical activity; *17*, 28 degrees C. rate increasing; *18*, 30 degrees C. regular rhythm has begun at slow rate; *19*, 33 degrees C.; *20*, 34 degrees C.; *21*, 35 degrees C.; *22*, 36 degrees C.; *23*, 37 degrees C.; *24*, 38 degrees C.

outside the membrane. Hypothermia and anoxia may cause changes in cell membrane permeability or destruction of some cells with liberation of potassium to increase the potassium concentration outside the persisting cell membranes. Acetylcholine may act in a similar fashion, since it is known that this material alters permeability of the cell

membrane to potassium ions, as indicated by Burgen and Terroux.

In attempting to substantiate this elementary concept, potassium determinations were done on the effluate collected during the first minute after starting reperfusion following a period of arrest. These findings compared with control indicate an increased potassium excretion following arrest in all cases. Further work on this point is being done. If the arrests are due to increased extracellular potassium concentrations whether due to an exogenous supply or to an accumulation from an endogenous source, then methods other than those utilizing potassium citrate or Sealy's mixture are achieving arrest as a secondary phenomenon.

On the basis of these studies, potassium citrate appears to be the best cardioplegic agent of the methods tested. It is simple to prepare and store, causes immediate arrest and rapid recovery, and following its use, there is complete return to initial amplitude of contraction and electrocardiographic pattern.

SUMMARY

1. The effects of potassium citrate, Sealy's mixture, acetylcholine, A.C.D. solution, anoxia, and hypothermia on the mechanical and electrical activity of the isolated perfused guinea pig heart have been evaluated and compared.

2. With the exception of anoxia, all of the methods tested cause almost immediate mechanical arrest of the heart followed shortly thereafter by electrical arrest.

3. Average time to mechanical arrest in anoxia was 5 minutes 8 seconds. Electrical arrest did not occur for as long as 70 minutes after anoxia was begun.

4. On reperfusion, initial mechanical activity recurred first after acetylcholine arrest and last after the use of A.C.D. solution. Return to maximum amplitude occurred earliest after potassium citrate and latest following anoxic arrest. Initial electrical activity returned first after acetylcholine and last after Sealy's mixture. There was fibrillation for 1 to 2 minutes when the heart was perfused after anoxia.

5. Using hypothermia, mechanical and electrical arrest was reached at a temperature of 16.2 degrees C. Return to initial mechanical activity occurred at 25.5 degrees C. although electrical activity had begun at 23 degrees C.

6. A possible explanation for the mechanism of arrest with all methods is discussed.

7. On the basis of these studies it is concluded that potassium citrate appears to be the best cardioplegic agent of the methods tested.

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# OBSERVATIONS ON THE EFFECT OF PORTACAVAL ANASTOMOSIS UPON THE HEMODYNAMICS OF THE LIVER

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PORTACAVAL ANASTOMOSIS has had widespread acceptance as the definitive treatment of bleeding esophageal varices. Despite this clinical acceptance only fragmentary data are available concerning the effect of the anastomosis upon hepatic hemodynamics. However, Redeker has recently published circulation studies on 10 cirrhotic patients preceding and following portacaval anastomosis. We have studied 6 patients before and after portacaval surgery. The present article outlines the techniques of study, the findings in these patients, and the integration of these findings with other published material.

## MATERIALS AND METHODS

The indications for portacaval anastomosis in these patients were: a previous episode of bleeding esophageal varices in 4, a previous episode of gastrointestinal bleeding and intractable ascites in 1, and intractable ascites in 1. In 5 of the patients cirrhosis developed on an alcoholic, nutritional basis; 1 (T. J.) had postnecrotic cirrhosis.

Prior to operation these patients were studied by hepatic vein catheterization, as previously described (6). On deep inspiration a cardiac catheter was "wedged" in a small hepatic venule. This occlusion of a peripheral venule produces a static column of blood that transmits the pressure in the hepatic sinusoidal bed to the catheter. This intrasinusoidal pressure represents a combined effect of portal vein and hepatic artery pressure. However, this pressure has been shown to be equivalent, in most instances, to portal vein pressure by the methods of Friedman and Reynolds and their associates. In the 2 patients with ascites a correction was made for the intra-abdominal pressure caused by the fluid. The gradient in pressure from the abdominal inferior vena cava to the thoracic inferior vena cava was subtracted from the hepatic wedged pressure. While this may not be entirely correct, in our experience the removal of ascitic fluid generally reduces the wedge pressure to the extent of this abdominal inferior vena cava-thoracic inferior vena cava gradient. Pressures were also taken in the hepatic vein, in the lower inferior vena cava, and right atrium. Following complete diversion of the portal blood flow by end-to-side portacaval anastomosis, the wedged hepatic vein pressure represents the intrasinusoidal pressure developed by the remaining perfusion source, the hepatic artery. Measurements were recorded with a Sanborn electromanometer and direct writing oscillograph; the manometer zero level was taken at an external estimation of the right atrium. Simultaneous blood samples

From the Cardiopulmonary Laboratory of the Department of Surgery, the Radioisotope Laboratory of the U. S. Naval Hospital, St. Albans, New York and the Department of Surgery of the State University of New York Downstate Medical Center.
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were drawn from the hepatic vein and from the brachial artery for the oxygen content.

In 5 of the patients hepatic blood flows were determined by a modified colloidal gold extraction technique previously described (2). Large colloidal particles are selectively removed from the blood by the liver, allowing the determination of a disappearance rate constant (K), as described by Vetter and associates (11). The liver blood flow is calculated by relating the K to the total blood volume (hepatic blood flow = disappearance [K] / min. × total blood volume in ml.). The blood volumes were determined by the radioactive iodinated human serum albumin technique. This hepatic blood flow method considers only the volume of blood perfusing liver sinusoids with functioning reticuloendothelial cells and is probably best called estimated effective hepatic blood flow. It will not measure the blood shunted through arteriovenous or venovenous shunts as described in cirrhotic livers. At laparotomy the portal vein pressure was measured with a saline manometer to correlate with the preoperative studies.

In these 6 patients an end-to-side portal vein to inferior vena cava anastomosis was performed. During convalescence, hepatic vein catheterization was again carried out and the preoperative determinations were repeated. In 4 instances the catheter was passed into the portal vein and superior mesenteric vein through the shunt and in 3 of these patients pressure measurements were made. The hepatic vascular resistance, the ratio of wedged hepatic vein pressure in millimeters of mercury to hepatic blood flow in milliliters per minute times 100, indicates the effects of altering one or both of these parameters. Processes such as cirrhosis that reduce blood flow and increase intrasinusoidal pressure cause an increase of this ratio. For example, the normal subject with a pressure of 10.5 millimeters of mercury and a flow of 1,100 milliliters per minute has a hepatic vascular resistance of 0.95. This index was determined preoperatively and postoperatively.

## RESULTS

*Preoperative studies.* The wedged hepatic vein pressures obtained preoperatively in these patients were abnormally elevated compared to our range in "normals" of 9 to 11 millimeters of mercury. The pressures obtained at catheterization correlated well with the pressures obtained at laparotomy previous to the portacaval shunt. The portal vein pressures were within 4.4 millimeters of mercury of the indirect measurements. There was a mean difference of 2.4 millimeters of mercury or 10 per cent between the wedged hepatic vein pressure and the portal vein pressure. All the indirect preoperative measurements were lower than the operating room portal vein pressures.

The hepatic blood flows were all markedly reduced in good correlation with histologic and biochemical evidence of advanced cirrhosis. The mean effective hepatic blood flow for these 5 patients was 430 milliliters per minute compared to a mean hepatic blood flow of 392 milliliters for advanced cirrhosis at this clinic and compared to a mean of 1,100 milliliters for "normals."

There was a wide range of arterial-hepatic vein difference and oxygen content. While the arterial-hepatic vein difference of patient A. Y. is elevated compared to the normals studied at this laboratory, the remaining arterial-hepatic vein differences were in the range of our normals.

The hepatic vascular resistance ordinarily, using the colloidal particle extraction technique for hepatic blood flow, is in the range of 1.0. These 5 patients preoperatively had elevated resistance values ranging from 3.0 to 11.0.

*Postoperative studies.* The wedged hepatic vein pressure fell in all patients following surgery. In 2, C. M. and T. J., however, the fall was probably insignificant. The others had falls of 29, 38, 45, and 58 per cent.

Following surgery 1 patient had an effective estimated hepatic blood flow that was

TABLE I.—SUMMARY OF PREOPERATIVE AND POSTOPERATIVE HEMODYNAMIC DATA OF 6 PATIENTS SUBJECTED TO END-TO-SIDE PORTACAVAL ANASTOMOSIS

| | Preoperative | | | | | Postoperative | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Patient and indication for surgery* | *Wedged hepatic vein pressure, mm. Hg* | *Hepatic blood flow, ml./min.* | *Arterial-hepatic vein $O_2$ diff., vol. per cent* | *Hepatic resistance* | *Portal vein pressure at laparotomy mm. saline (mm. Hg)* | *Wedged hepatic vein pressure, mm. Hg* | *Hepatic blood flow, ml./min.* | *Arterial-hepatic vein $O_2$ diff., vol. per cent* | *Hepatic resistance* | *Remarks* |
| A.Y. Bleeding esophageal varices | 17.1 | 485 | 7.1 | 3.5 | 280 (20.6) | 12.2 | 231 | 1.5 | 5.3 | The superior mesenteric vein was catheterized postoperatively, no pressure measurement was taken |
| M.S. Bleeding esophageal varices | 29.0 | 391 | 4.5 | 7.4 | 430 (31.6) | 18.0 | 178 | 7.5 | 10.1 | The portal and superior mesenteric veins were catheterized postoperatively; the pressures were 10 and 11.9 mm. Hg respectively |
| T.J. Bleeding esophageal varices | 21.0 | 515 | 5.8 | 4.1 | 300 (22.1) | 19.0 | 250 | 8.4 | 7.6 | In 7/46 the portal vein pressure was 415 mm. saline at operation for liver biopsy. Splenic pulp pressure was 140 mm. saline at the time of postoperative hepatic vein catheterization |
| C.M. Bleeding esophageal varices | 24.0 | — | — | — | 340 (25.0) | 23.0 | — | — | — | — |
| M.B Intractable ascites | 23.8* | 487 | 3.0 | 4.9 | 350 (25.7) | 10.0 | 231 | 2.9 | 4.4 | The portal vein pressure was 6.2 mm. Hg at postoperative catheterization |
| D.S. Bleeding esophageal varices and intractable ascites | 30.9** | 273 | 4.7 | 11. | 480 (35.3) | 17.0 | 245 | 4.6 | 6.9 | The superior mesenteric vein pressure was 8 mm. Hg at postoperative catheterization |

*5.1 mm. Hg gradient between abdominal inferior vena cava and thoracic inferior vena cava.
**3.9 mm. Hg gradient between abdominal inferior vena cava and thoracic inferior vena cava.

minimally changed (10 per cent). The remaining 4 had blood flows that declined 54, 52, 51, and 53 per cent.

Two of the patients had essentially unchanged arterial-hepatic vein oxygen difference, in 2 the arterial-hepatic vein difference increased, and in 1 the difference markedly decreased.

The 3 patients A. Y., M. S. and T. J., who were operated upon for previous bleeding from esophageal varices, had increased hepatic vascular resistance following surgery. The patient (M. B.) operated upon for intractable ascites remained essentially unchanged, and the patient (D. S.) who had previous bleeding esophageal varices and intractable ascites as an indication for operative therapy had lowered resistance.

During the postoperative catheterization it was possible to introduce the catheter through the portacaval shunt in 4 of 5 patients in whom it was attempted. In 3, the pressure in the portal vein, superior mesenteric vein, or splenic vein was obtained. The pressures were normal for the portal system (6.2 to 11.9 mm. Hg).

Patient D. S., operated upon 14 months ago, has been catheterized twice since the postoperative study reported in Table I (6 months and 12 months postoperatively). Her wedge pressure has remained unchanged (16.0 mm. Hg on both occasions). Her estimated effective hepatic blood flow has also remained stable (207 ml./min.).

TABLE II.—THE EFFECTS OF PORTACAVAL ANASTOMOSIS ON HEPATIC BLOOD FLOW

| *Author* | *Patient* | *Technique* | *Hepatic blood flow Preop. ml./min.* | *Postop. ml./min.* | *Per cent change* | *Type operation* |
|---|---|---|---|---|---|---|
| Nardi | S.F. | Radioactive colloidal chromic phosphate | 1838 | 714 | −61 | Splenorenal anastomosis |
| | L.L. | | 2757 | 1327 | −52 | |
| | C.C. | | 1812 | 1128 | −38 | |
| | C.S. | | 1854 | 1400 | −24 | |
| | R.B. | | 1790 | 1473 | −18 | |
| | T.G. | | 972 | 1054 | + 4 | |
| | L.W. | | 1856 | 2074 | +12 | |
| Bradley *et al.* | P.P. | BSP—Fick | 960 | 710 | −26 | Splenorenal anastomosis |
| | K.N. | | 1030 | 940 | − 9 | |
| | P.N. | | 1220 | 960 | −21 | |
| | H.C. | | 1340 | 760 | −43 | |
| | T.K. | | 1720 | 1490 | −13 | |
| | A.R. | | 940 | 480 | −49 | Side-to-side portacaval anastomosis |
| | N.P. | | 1310 | 1030 | −21 | |
| | S.W. | | 1330 | 500 | −62 | |
| | E.K. | | 1780 | 950 | −47 | End-to-side portacaval anastomosis |
| | P.McC. | | 1030 | 630 | −39 | |
| Redeker *et al.* | R.R. | BSP—Fick | 2910 | 710 | −76 | End-to-side portacaval anastomosis |
| | C.M. | | 1790 | 1105 | −38 | |
| | T.S. | | 1790 | 2080 | +16 | |
| | J.R. | | 1630 | 695 | −57 | |
| | M.S. | | 1500 | 630 | −58 | |
| | M.L. | | 1410 | 570 | −60 | |
| | C.W. | | 1150 | 755 | −34 | |
| | J.A. | | 1020 | 365 | −64 | |
| | C.H. | | 920 | 410 | −55 | |
| | J.J. | | 815 | 690 | −15 | |
| Gliedman *et al.* | A.Y. | Radioactive colloidal gold | 485 | 231 | −52 | End-to-side portacaval anastomosis |
| | M.S. | | 391 | 178 | −54 | |
| | T.J. | | 515 | 250 | −51 | |
| | M.B. | | 487 | 231 | −53 | |
| | D.S. | | 273 | 245 | −10 | |

Patient M. B., operated upon 16 months ago, was recatheterized 1 year following surgery. Her wedged hepatic vein pressure was unchanged from the convalescent determination (10 mm. Hg).

## DISCUSSION

Because of the limitations of evaluating such a small group, the results in our 6 patients will be reviewed with other similar published data. The reports of Nardi, Bradley, Redeker, and Ekman were used as sources.

The differences in methods between groups make comparison of absolute values impossible. For example, the colloidal extraction technique for determining hepatic blood flow yields a generally lower value than the bromsulfalein technique described by Vetter and associates (12). Differences in the manometer zero point change the hepatic wedge pressure. Redeker subtracts the inferior vena cava pressure from the hepatic wedge pressure to obtain a "net pressure"; Ekman uses the midaxillary line for his manometer zero point. To obviate the difficulties in equating technique, we will compare per cent change from preoperative to postoperative state only. Presumably, whatever the techniques, they have been consistently applied and per cent change should be a generally valid comparison in spite of absolute value differences.

There seems to be no doubt that a successful shunt decreases the hepatic blood flow, whether the determination be made by a colloidal extraction technique or by the "BSP-Fick" technique. In our 5 patients, the mean decline was 44 per cent following shunting, ranging from 10 to 54 per cent.

Other published hemodynamic data (Table II) show a 44 per cent decline for all other patients with a similar end-to-side portal vein to inferior vena cava anastomosis. Splenorenal anastomosis caused a 24 per cent decline. The difference in per cent decline would insinuate a lesser propensity for the splenorenal anastomosis to divert blood from the liver. Unfortunately, no data were available on the effect of splenorenal shunts on the hepatic wedge pressure.

The determination of hepatic wedge pressure in our studies as well as the other reported data concerns patients subjected to end-to-side portacaval shunts. The hepatic wedge pressure declined in our 6 patients, a mean of 31 per cent compared to 37 per cent for all other published studies. In contrast to this effect of shunting procedures upon the hepatic wedge pressure, Reynolds found a mean decline of but 11 per cent in 5 patients following hepatic artery ligation. This lack of effect upon the hepatic wedge pressure with an intact portal vein suggests failure of the latter procedure to lower portal hypertension. While the shunting procedures caused a general decrease in hepatic wedge pressure, there was no clear correlation between the degree of decline in the hepatic blood flow and the decline in the wedged hepatic vein pressure.

The 5 patients in the collected study subjected to shunting with ascites had a mean fall in pressure of 51 per cent. However, the few cases under discussion make profound interpretation presumptuous. The relationship of hepatic wedge pressure and hepatic blood flow to ascites is still unclear. The 2 patients whom we have studied have remained free of ascites for 14 and 16 months on unlimited salt diets. Both of these had marked falls in pressure following surgery. Patient D. S. has occasional mild pedal edema following very large salt intake. Patient M. B. has a normal wedged hepatic vein pressure 16 months after surgery and a marked improvement in liver chemistries. In both patients the 24 hour urinary salt excretion has gone from less than 1 milliequivalent per 24 hours on an unlimited salt diet to over 100 milliequivalents per 24 hours. The 3 other patients, noted in Table III, who had ascites at the time of surgery have also been free of ascites following portacaval shunts (according to the authors who have published the studies). This observation supports Eisenmenger and Nickel as to the importance of portal hypertension in the production and maintenance of ascites.

TABLE III.—THE EFFECT OF END-TO-SIDE PORTACAVAL ANASTOMOSIS ON WEDGED HEPATIC VEIN PRESSURE

| | | *Wedged hepatic vein pressure* | | *Per cent change* |
|---|---|---|---|---|
| | | *Preop.* | *Postop.* | |
| *Author* | *Patient* | *mm. Hg* | | |
| Ekman | H.E. | 37 | 42 | +14 |
| | O.B.* | 31 | 18 | −42 |
| | S.S.* | 37 | 11 | −70 |
| | B.S. | 26 | 15 | −42 |
| | S.F. | 29 | 18 | −38 |
| | K.B. | 22 | 15 | −32 |
| | K.N. | 24 | 12 | −50 |
| Redeker *et al.* | R.R. | 14 | 11 | −21 |
| | C.M. | 17 | 13 | −24 |
| | T.S. | 17 | 10 | −41 |
| | J.R.* | 21 | 13 | −38 |
| | M.S. | 22 | 11 | −50 |
| | M.L. | 21 | 12 | −43 |
| | C.W. | 15 | 12 | −20 |
| | J.A. | 18 | 9 | −50 |
| | C.H. | 20 | 9 | −55 |
| | J.J. | 19 | 13 | −32 |
| Gliedman *et al.* | A.Y. | 17.1 | 12.2 | −29 |
| | M.S. | 29.0 | 18.0 | −38 |
| | T.J. | 21.0 | 19.0 | −10 |
| | C.M. | 24.0 | 23.0 | − 4 |
| | M.B.* | 23.8 | 10.0 | −58 |
| | D.S.* | 30.9 | 17.0 | −45 |

*Ascitic.

Three of our patients had an increase in hepatic vascular resistance following shunting. Redeker reported 8 patients of 10 as showing an unchanged or increased hepatic resistance. This generally increased resistance stresses the greater decline in liver blood flow compared to hepatic wedge pressure and emphasizes the severe contraction of the liver perfusion bed. The 40 per cent decline in the hepatic blood flow following a portacaval shunt is generally not sufficient to lower intrahepatic sinusoidal pressure to normal.

The hepatic wedge pressure in the pa-

tients reported appears to be a good indication of the portal pressure. However, in patients with extrahepatic obstruction the correlation is poor. We have studied a patient with so-called cavernomatous transformation of the portal vein. This patient's hepatic wedge pressure was 10 millimeters of mercury. At laparotomy his portal vein pressure was 27.9 millimeters of mercury (380 mm. saline). In addition, Ekman has found a poor correlation between hepatic wedge pressure and splenic pulp pressure in some of his patients. Reynolds and ourselves, on the other hand, have found a generally good correlation between the preoperative wedge pressure and the portal vein pressure at laparotomy. We have had, in 1 patient, a marked disparity (16 mm. Hg) between the wedged hepatic vein pressure and the portal vein pressure. During the course of surgery lymph was noted to be dripping from the surface of the liver. In this patient severe intractable ascites developed following the shunting procedure. Her abdomen was distended and diaphragm elevated to the point of respiratory embarrassment, requiring daily paracentesis. To maintain the blood volume and plasma stores of protein she was transfused with the paracentesis fluid daily. Unfortunately, she succumbed 6 weeks following the shunting procedure from what appeared to be a cerebrovascular accident before her postoperative hemodynamic data could be obtained.

The clinical significance of the reported hemodynamic data remains to be answered by larger groups of patients. In a group of approximately 20 infectious hepatitis patients, we have noted a decrease in hepatic blood flow at the height of the clinical manifestations of the disease. With subsidence of the hepatitis and with clinical improvement, the hepatic blood flow increases, returning to normal during convalescence. In a small group of cirrhotic patients we have noted a similar occurrence. Patient T. J., for example, entered the hospital jaundiced, ascitic, and bleeding with marked liver failure. He was observed for 1 year before surgery was undertaken. Shortly after admission his estimated effective hepatic blood flow was 150 milliliters per minute, 3 months later his hepatic blood flow went to 300 milliliters per minute, 330 milliliters was recorded 3 months later, and 6 months later, preoperatively, it was 515 milliliters. This continuing increase in hepatic blood flow might be an indication for a delay in operation until the hepatic flow stabilizes. Presumably, as the edema of the liver and cellular infiltration decreases, hepatic perfusion increases. These observations must be further substantiated by a larger group of cirrhotic patients. We have been guided by the hepatic wedge pressure in choosing patients for surgery. The periodic waxing and waning of varices as well as the difficulty in demonstrating them emphasizes the need for objective methods to determine portal hypertension. Both splenic pulp pressure and hepatic wedge pressure apparently give reliable results. Interest in what occurs to hepatic perfusion following surgery prompts the use of the wedge determination. Presently we are using both techniques. The splenic pulp pressure is used to monitor portal vein pressure directly; the hepatic wedge pressure is used to follow the hepatic sinusoidal pressure. The catheter technique also permits direct catheterization of the portal vein and tributaries following shunting procedures.

SUMMARY

1. The wedged hepatic vein pressure, estimated hepatic blood flow, and hepatic resistance were determined before and after an end-to-side portacaval anastomosis in 5 patients. The wedged hepatic vein pressure alone was determined before and after surgery in 1 other patient.

2. The preoperative wedged hepatic vein pressures in the 6 patients were elevated. There was a mean difference of 2.4 millimeters of mercury or 10 per cent between the preoperative measurement and the direct portal pressure obtained at surgery. The wedged hepatic vein pressure fell a

mean of 31 per cent (ranging from 4 to 58 per cent) following the portacaval shunt.

3. The preoperative estimated hepatic blood flow, determined by a colloidal particle technique, was compatible with advanced cirrhosis. Following surgery there was a mean decline of 44 per cent (ranging from 10 to 54 per cent).

4. The hepatic vascular resistance was increased in the 5 patients before surgery. The resistance further increased in 3, remained essentially unchanged in 1, and declined in 1 following operation.

5. Two patients who had intractable ascites at the time of operation have been free of ascites for 14 and 16 months.

6. Comparable studies by other authors have been reviewed and related to the findings in our patients.

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# THE SIGNIFICANCE OF LIVER DYSFUNCTION IN MOUTH CANCER

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MOUTH CANCERS comprise about 5 per cent of all cancers. Etiologically, squamous cell carcinoma of the mouth has been associated with syphilis, chronic irritation, carcinogenic tars, and use of tobacco and alcohol. The apparent predilection to oral carcinoma of a small segment of the population suggests probable predisposing factors.

In a previous report (8), the significance of chronic hepatic disease was mentioned as a possible predisposing factor in cancer of the tongue. The present study was undertaken to identify further the incidence of liver dysfunction in patients with cancer of the floor of the mouth, palate, and tonsillar fossa.

## MATERIALS AND METHODS

*Selection of patients.* Records were reviewed of all patients at the Tumor Clinic of the Massachusetts General Hospital with a diagnosis of epidermoid carcinoma of the palate, tonsillar fossa, or floor of mouth, during the years 1946 to 1957. Of the 152 patients representing the total number of cases seen at the clinic during this 10 year period, the records of 84 patients were incomplete with regard to adequate history, physical examination, or laboratory data. The records of 68 patients were sufficiently complete to furnish adequate data on serologic examination, smoking, alcoholic consumption, and physical and laboratory examination.

*Factors examined.* Tobacco.—Of 68 patients with oral cancer, 66 (97 per cent) smoked 20 or more cigarettes a day, or the equivalent in other forms of tobacco. Only 2 patients were nonsmokers. These findings parallel the observations of Wynder and associates (9, 10) on the percentage of smokers with carcinoma of the intrinsic and extrinsic larynx and mouth cancer, and our previous findings in patients with tongue cancer (8). Data are insufficient to permit analysis in regard to duration of smoking habit, and forms and combinations of forms of use.

Alcohol.—A minimum of six "hard" drinks per day, or the equivalent in wine or beer was considered as evidence of habitual alcoholism. Of the 68 patients with complete histories and studies, 51 (75 per cent) were habitual or excessive users of alcohol. This number compares closely with the 76 per cent of habitual alcoholics among the 108 cases of tongue cancer previously studied.

Syphilis.—Six patients (9 per cent) gave a positive history of syphilis and had positive serologic tests. Five of these patients also had alcoholic cirrhosis.

Oral irritants.—The dental aspects of mouth cancer are difficult to define. In our study of tongue cancer (8), 70 per cent of the patients presented definite evidence of longstanding irritation from sharp, broken or eroded teeth, or poorly fitting dentures.

The locations of cancers under consideration in this report, floor of mouth, tonsillar fossa, and palate, offer controlled information relative to chronic oral trauma. Fifty-four per cent of 68 patients presented definite chronic irritation. Poorly fitting dental prostheses are obviously of possible significance only in relation to lesions of the palate and the floor of the mouth, but of no significance for lesions beyond the denture bearing area.

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Of 21 patients with carcinoma of the floor of the mouth, 13 (62 per cent) presented evidence of chronic irritation. Of 43 patients with cancer of the tonsillar fossa, 20 (46 per cent) presented evidence of chronic trauma. Carcinoma of the hard palate was not observed in patients who wore artificial dentures, suggesting that the hard palate is protected from carcinogenic tars by the prosthesis.

Hepatic disease.—Forty (59 per cent) of the total of 68 patients with mouth cancer had unequivocal evidence of hepatic cirrhosis, as established by physical examination and confirmed by liver function tests. Six additional patients had histories of chronic cholecystitis, jaundice following exposure to hepatotoxins such as carbon tetrachloride or naphtha, or severe nutritional deficiencies.

Combinations of factors.—One or more of these predisposing or precipitating factors were operative in all but 2 of the series, and multiple factors were present in 59 of the patients (87 per cent). Of the group with multiple factors, 97 per cent smoked to excess and 75 per cent used alcohol to excess.

FINDINGS

*Sex.* Of the total group of 152 patients, there were 18 females (13.5 per cent) and 134 males; a ratio of 1: 7.5. The females showed a rather marked incidence of hepatic dysfunction and use of tobacco. This is in contrast to the previously reported study of tongue cancer (8) in which the majority of females were not alcoholic, but did present other conditions modifying the mucosal substrate, e.g., Plummer-Vinson's syndrome. The females in the present series averaged 5 years younger than the males, and all were postmenopausal. In our study series, 8 of the 9 patients were heavy smokers, 7 presented evidence of hepatic disease, 3 had chronic cholecystitis, and there were 3 with severe malnutrition, including 1 with Plummer-Vinson's syndrome.

*Age.* The mean age of the 68 patients with cancer of the floor of the mouth, tonsillar fossa, or palate was determined at two levels. Forty patients identified as having had hepatic cirrhosis at the time of diagnosis of their oral carcinoma averaged 57 years of age.

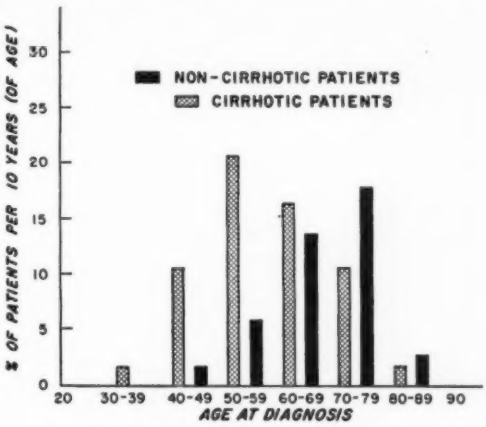


FIG. 1. Age at diagnosis of mouth cancer indicates an earlier onset for those patients with concomitant hepatic cirrhosis. The median age for cirrhotics with carcinoma of the mouth is 57 years, while it is 70.2 years for those patients without cirrhosis.

In the second group, those patients without demonstrable cirrhosis, oral carcinoma developed at the age of 70.2 years. This fact indicates a significant difference between these two groups. In patients with hepatic cirrhosis, oral cancer developed 13 years earlier, on the average, than in those without hepatic disease (Fig. 1).

Women, as a group, averaged 52 years of age at the time of diagnosis of their oral carcinoma. This observation supports findings noted in a previous report (8), in which the mean age for females was 5 years earlier than male patients.

*Survival* (*Fig. 2*). Survival data were computed with due consideration for withdrawals and deaths from other causes and therefore represent a "real" survival curve based on life tables, as suggested by Merrell and Shulman.

The over-all 5 year survival for male and female patients with carcinoma of the floor of the mouth, palate, or tonsillar fossa, who had concomitant cirrhosis of the liver, was

FIG. 2. Five year survival and death from carcinoma of the mouth. Patients having mouth cancer and hepatic cirrhosis have a much poorer prognosis, despite the type of treatment and the earlier age of onset of the carcinoma.

19 per cent. This group of patients is compared with a second group having oral carcinoma but no hepatic cirrhosis. Five year survival in this second group was 40.3 per cent. These findings confirm previous studies of cancer of the tongue in which the 5 year survival rate for patients with concomitant hepatic cirrhosis was also 19 per cent (8).

Again, despite the type of treatment for oral carcinoma, prolonged survival favored the noncirrhotic group notwithstanding their more advanced age at the onset of their cancer.

*Multiple primary carcinomas.* Of the total group of 68 patients with cancer of the mouth there were 12 additional primary epithelial cancers. These occurred in 10 patients. Sites of additional primary carcinomas included lung, esophagus, tongue, larynx, uvula, soft palate, and floor of the mouth.

## DISCUSSION

This report is subject to the numerous problems inherent in a retrospective study. Hospital records are frequently inadequate when they are re-evaluated in a search for specific data. Notwithstanding the limitations of this method, a large number of cases is available which serves as a reliable guide to a study on the etiology of cancer of the mouth.

While a large percentage of people in this age group are adjudged to have evidence of oral and dental irritation, this study suggests a distinct role attributable to these agents. In comparing carcinoma of the floor of the mouth, in which defective dentures and other dental irritants may act, with a group of patients with carcinoma of the tonsillar fossa, there is found a significant difference in the presence of such irritants. A poorly fitting prosthesis may be said to play a role in cancer of the mouth, which is easily as significant as that of syphilitic infection, often given such prominence in previous studies.

In the past, a number of investigators have remarked on the apparent high incidence of alcoholic patients observed with carcinoma of the mouth and tongue. Frazer in Scotland, Ahlbom and Jacobson in Sweden, Martin and Martin and Wynder (9, 10) in this country, all cite heavy alcohol consumption as a significant contributing factor in cancer of the mouth.

The findings presented in this study show that heavy alcohol consumption was present in 75 per cent of patients with cancer of the floor of the mouth, palate, and tonsillar fossa. The incidence of overt hepatic cirrhosis was 58.8 per cent of 68 patients who were thoroughly evaluated while admitted to the Massachusetts General Hospital for treatment of mouth cancers. This figure does not represent the additional group of 84 patients with oral carcinoma, in which adequate information was lacking in the hospital records.

The exact role or mode of action of alcohol in the genesis of oral cancer is, of course, unknown. One may speculate with the aid of available data, that the local effect of alcohol on the oral mucosa may be of lesser importance, and secondary to a generalized change in the mucosal substrate via malnutrition and resultant hepatic dysfunction. This contention is borne out by the group of patients studied who were nonalcoholic cirrhotics and in whom carcinoma of the mouth developed. The importance of malnutrition and hepatic disease

is further suggested by the work of others. In India, where the problem of malnutrition is rife, and the average life-span is greatly reduced, oral carcinomas comprise more than 50 per cent of all cancers.

These data foster the concept of cocarcinogenesis, a conditioned substrate upon which factors such as chronic irritation and tobacco may act. These data further suggest that, even in the presence of a conditioned mucosal substrate with superimposed carcinogens and irritants, the process of development of oral carcinoma is slow and may take up to 20 years or more. Mouth cancer developed at an earlier age in those patients who had a diagnosis of hepatic cirrhosis confirmed. In 10 patients additional primary mucosal cancers developed.

The nature of the altered substrate and what may be responsible for its alteration remains an intriguing problem. Estrogenic hormones have often been implicated in studies on the etiology of carcinoma. In a recent report, Barr and Sommers indicate that in human males excess estrogen associated with hepatic cirrhosis may be cocarcinogenic for liver tissue, and perhaps play a role in the development of prostatic cancer as well. Nathanson and Weisberger in 1939 successfully treated oral leucoplakia with estrogenic hormones, and thereby implicated a possible deficiency or alteration in the metabolism of the sex hormone, evoking a substrate change which rendered these patients more susceptible to the development of mucosal cancer.

Epidermoid carcinoma of the mouth has not been observed, at this hospital, in a premenopausal female who did not have evidence of liver impairment. The effect of menopause on mucous membranes is obscure.

Alteration of the mucous membrane substrate may be due to disorders of mineral metabolism, often seen with liver disease. The role of zinc and other heavy metals in the problems of cirrhosis, Plummer-Vinson's disease, hypovitaminosis A, pernicious anemia, and their effect upon mucous membranes certainly requires further study.

It is apparent that this study raises many questions which cannot be answered at present. Further investigations are in progress which may help to solve some of them.

## SUMMARY AND CONCLUSIONS

1. All cases of carcinoma of the floor of the mouth, tonsillar fossa, and palate diagnosed at the Tumor Clinic of the Massachusetts General Hospital between 1946 and 1957 were reviewed.

2. Of the total of 152 patients, 68 had recorded information relative to the 5 "etiologic categories": tobacco and alcohol consumption, syphilis, oral irritants, and hepatic disease.

3. Data are presented showing a sex incidence of 7.5 males to 1 female with oral cancer. Survival studies indicate a significant difference if the patients are presented in two distinct groups, i.e., those with hepatic cirrhosis, and those patients without demonstrable hepatic cirrhosis. Cirrhotics with mouth cancer have a 19 per cent 5 year survival rate, while 40.3 per cent of those patients without cirrhosis survive at least 5 years.

4. The average age at diagnosis for patients with carcinoma of the mouth *and* hepatic cirrhosis is 57 years, while it is 70 years for those patients without cirrhosis. The average for females with carcinoma of the mouth is 52 years of age.

5. Oral irritants play an important role in mouth cancer, particularly if patients with floor of the mouth lesions are compared with those harboring tonsillar fossa carcinomas. The wearing of a dental prosthesis appears to protect from carcinoma of the hard palate.

6. Ninety-seven per cent of the group studied smoked more than 1 pack of cigarettes per day. Seventy-five per cent of the patients drank alcohol to excess, and 58.8 per cent of the total group had alcoholic cirrhosis, while an additional 9 per cent had nonalcoholic cirrhosis. Nine per cent of the total group had syphilis, and all but 1 of these patients were cirrhotic as well.

7. Ten patients of the 68 studied presented additional multiple primary carcinomas of the upper gastrointestinal or respiratory tracts, in addition to the oral cancer.

8. The concept of co-carcinogenesis and multiple causation in cancer of the mouth is discussed with reference to a mucosal substrate previously altered by the development of hepatic disease. The factors of carcinogenic tars and chronic oral irritants are then superimposed on this prepared substrate to yield, with time, a carcinoma.

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# EDITORIALS

## BACK TO LISTER

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THE ADVENT of penicillin-resistant strains of staphylococci and an increasing number of postoperative infections reported throughout the world literature have caused consternation and bewilderment. The immediate culprit picked upon is penicillin, which, because of its promiscuous use, has led to the development of this resistant strain. We seem to forget the great blessing which this antibiotic has been to mankind, the countless lives it has saved, and the operative fields which have been opened up under its protection. It is still a very useful and helpful agent and should not be condemned because nature has found a way of combatting it. Such a course of events should have been foreseen. It has been the same with DDT; the great blessing it proved to be when Naples was threatened with typhus cannot be belittled by the fact that flies have now become acclimated to the agent.

What then is the answer to the increase in postoperative infections which seem to be facing us today? Is it to discontinue the use of penicillin and go to newer and more potent antibiotics? Or should our search proceed along other lines?

I think we might say the penicillin is to blame, but not for the reason usually given. Penicillin, because of its almost magical control of infection, seemed to be the answer to our demand for a universal sterilizing agent. Under its protection one need have no fear of bacterial infection, and aseptic precautions seemed hardly necessary. The old 10 minute scrub was a waste of time since newer cleansing agents left the skin almost bacteria-free, and besides, penicillin would take care of infection anyway. However, the staphylococcus outsmarted us, just as the fly has outsmarted us, and has learned to deal with the counteragent. Consequently, with a letdown in protective measures the organism gains entrance into wounds, just as the flies get in when we leave screens off the windows, DDT or no DDT.

The profession is now engaged in a tremendous, almost world-wide effort, to ferret out the causes of the increase in postoperative infections. Numerous and various sources are being studied—blankets, traffic in the operating area, and many other possible sources are being studied by the most scientific of techniques. Even the air of the operating rooms is being studied and analyzed for bacterial content, a procedure which takes us at once back to Lister. The experiments of Meleney made 20 years or more ago are being redone, to show what? To show that the most potent sources of postoperative infection come from people!

Surely penicillin is to blame, not because it has led to the development of resistant strains, but because under its soothing influence we, as surgeons, have become careless in asepsis. We have been wooed into complacency and have neglected the safeguards established years ago. Certainly the search for sources must continue—we must still culture our throats and filter the air and cut down on operating room traffic—

but we must also remember those simpler precautions we took before antibiotics came in to prevent wound contamination: the simple avoidance of fingering wounds and dressings, the masking of personnel and other less spectacular but important principles of asepsis. Surely absolute asepsis is desirable, but we often forget the need to handle tissues carefully and gently, to avoid operative trauma as much as possible and to maintain rest for the operative area, since the tissues themselves have been battling bacteria for ages and can deal with minimal contamination. How many surgeons dress their patients' wounds, wearing a mask and using sterile instruments? How many of the simpler precautions are we forgetting in our search for the unusual and the bizarre? How closely do we supervise wound care and dressings? How much of our work do we delegate to unskilled hands?

The rise in infection rate is not "just one of those things." It has a cause and even if the bacteria accountable for it are unusual, the bacteria must still get into wounds and incisions to cause the trouble. If they get in, regardless of the source, it means our asepsis has broken down. If it is found in the nose and throat of surgeon or hospital personnel, it simply means we are not masking effectively and are not protecting incisions from spray contaminants. The break-down is not in the fact that newer channels of contaminants are appearing, but that our carelessness or complacency with regards to old well known sources of trouble is evident.

Therefore, it seems fitting that our aim be to go back to Lister and recognize that bacteria must be kept out of wounds if we are to avoid infections.

# NEW ARTERIES FOR OLD

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THE DEVELOPMENT of arterial substitutes has been one of the outstanding achievements of the past decade, comparable in significance to the development of operations for the patent ductus, tetralogy of Fallot, and coarctation, that distinguished the preceding decade. Only 10 years ago vascular surgery comprised the treatment of varicose veins, arteriovenous fistula, and uncomplicated cases of coarctation of the aorta while today every inch of the aorta and its major branches has been replaced or bypassed in the treatment of arterial disease, and application of these methods to terminal vessels is imminent.

The event which liberated vascular surgery and emboldened the surgeon to apply his techniques to practically the entire vascular system; the event which, in fact, elevated vascular surgery to its position as a legitimate surgical field, was the epochal report of Robert Gross in 1949 concerning the experimental and clinical use of arterial homografts in the treatment of coarctation of the aorta. The development of methods for sterilizing and preserving homografts and the establishment of blood vessel banks were logical sequels to this pioneering work of Gross.

Efforts to find suitable artificial substitutes proceeded almost concurrently with the investigation of homografts. Contemporary interest in synthetic materials actually began about 8 years ago in the surgical laboratories at Presbyterian Hospital in New York. Voorhies, a surgical resident at Presbyterian, had been conducting some experiments in which mitral insufficiency was produced by passing a suture through the wall of the left ventricle so as to hook a chorda tendinea. When one of these animals was sacrificed, Voorhies observed that one of the sutures was lying within the ventricle and was completely covered with a thin membrane of fibrin. There was no microscopic evidence of attached thrombi. On the basis of this observation it was postulated "that if arterial defects were bridged by prostheses constructed of fine mesh cloth, leakage of blood through the walls of the prosthesis would be terminated by the formation of fibrin plugs and thus would allow the cloth tubes to conduct arterial flow. In the absence of foreign body reaction, it was anticipated that massive thrombosis would not occur; that fibroblasts would grow into the interstices of the mesh replacing the fibrin plugs and that the fibroblasts would then serve as a basis for endothelial proliferation or undergo sufficient adaptation to form a functional intima."

This prescient observation led to a series of experiments in which prostheses made of vinyon N cloth were implanted into the abdominal aorta of dogs. The success of these experiments, reported in 1952, led to clinical use of synthetic vascular substitutes. Hufnagel employed prostheses of dacron cloth; Shumacker used nylon and DeBakey reported success with orlon coated with vinyl plastic. Sanger introduced a knitted orlon graft and Grindlay and Lewis separately described prostheses made of polyvinyl (ivalon) sponge. With the exception of ivalon, all of these materials appeared to function satisfactorily in vessels of large caliber but the results in peripheral arteries were almost uniformly poor. Then, at the meeting of the Society of University Surgeons in 1955, Edwards and Tapp reported their preliminary experiments with a crimped, braided, nylon tube. Edwards has described the way in which the crimping process was discovered as follows: Doctor

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Tapp had placed a braided tube on a straight metal rod and dipped it into formic acid. In attempting to slide the tube off the rod the end stuck tight and the remainder of the graft was folded into accordion pleats. When finally removed it was noted to be flexible and to bend in any direction without collapsing. Because of the flexibility afforded by the crimping, these prostheses were especially useful for bypass operations on peripheral arteries.

Today at least 5 types of synthetic vascular substitutes are commercially available, and there has been sufficient experience with each of them to demonstrate their satisfactory clinical performance. As a consequence of their ready availability, these artificial grafts are rapidly replacing the homograft in the treatment of vascular lesions.

One of the most interesting features of the synthetic blood vessel is the marvelous way in which this foreign material is accepted and adapted to perform a specific function. Essentially this is organ formation, the synthetic fiber providing the stroma and the biologic elements of the recipient the parenchyma. In the beginning, formation of clot within the interstices of the cloth prevents leakage through the graft and enables it to conduct blood. Subsequently, fibrous connective tissue cells grow into the interstices and invade the fibrin deposits in the wall of the prosthesis and lining its inner surface. In the early stages this process is no different from the formation of granulation tissue anywhere in the body. Grossly, the lining membrane is red, soft, and succulent and is thrombogenic. As time goes by, however, the granulation tissue is converted into fibrous connective tissue by a process of maturation. This implies that the membrane becomes less cellular, and the innermost connective tissue cells become elongated and flat. At this stage the lining membrane of the synthetic replacement appears gray-white and glistening and is no longer thrombogenic. Thus, through a peculiar process of adaptation this layer, while basically nothing but connective tissue, has now become suited to its endothelial role and is entirely compatible with its internal environment, blood.

This sequence of events casts considerable doubt upon earlier explanations for regeneration of vascular endothelium. It was formerly believed that endothelium lost from an area of a functioning blood vessel, or replaced in the case of an arterial homograft, was derived from the true endothelium of the recipient vessel. The formation of a new endothelial lining thus came about by growth from each end of the segment. It is now evident that except for extremely short segments, this does not occur and in fact, the formation of an endothelial lining, whether in a natural blood vessel or in a synthetic prosthesis probably comes about as a result of selective adaptation of fibrous connective tissue.

Another interesting and unusual feature of synthetic grafts is their ability to function as vascular channels when uncovered by surrounding soft tissues or in the presence of infection. This property is not possessed by homografts since they are dependent upon adjacent tissues for their blood supply. A number of instances have been recorded in which synthetic grafts were utilized to replace segments of arteries destroyed by traumatic injury of the extremities. Lacking sufficient soft parts to cover the grafts, these were left completely exposed except at the anastomoses. The grafts have functioned under these circumstances for as long as 3 months thus preserving viability of the extremity.

Once arterial continuity has been restored and the artery left exposed because of inadequate soft tissues for coverage, a new problem is created, namely, what to do about the exposed graft. Although experience with this dilemma is limited it appears that granulations will not completely cover the graft and infection—a natural occurrence in any chronically open wound—will eventually reach the lines of anastomosis, and disruption will ensue. There are at least 3 possible solutions to this problem. First, if

there is sufficient uninvolved soft tissue adjacent to the wound a bypass graft can be inserted between the artery proximal to the wound and the segment distal to it. Second, the wound can be treated with topically applied bactericidal agents such as neomycin and bacitracin and the graft covered with a pedicle flap or a split thickness skin graft. Finally, using a Silverstone clamp the artery proximal to the graft can be gradually occluded permitting the development of collateral circulation and subsequent ligation of the vessel and removal of the infected graft. The first two methods are more desirable than the last since they do not interfere with blood flow to the extremity distal to the wound.

The appearance of infection of a synthetic graft after operations to bypass or replace segments of the aorta or peripheral arteries is a much more serious problem than that of infection of grafts which are intentionally exposed. Infection may be manifested first by involvement of the anastomoses and disruption of the suture lines with severe hemorrhage, or the process may smolder for weeks, even months, after operation. In the former instance the diagnosis is immediately evident and treatment must be instituted promptly. If the graft is in a peripheral artery, repair of the disrupted anastomosis is out of the question, and the graft should be removed and the artery ligated. Involvement of a graft in the aorta or common iliac arteries necessitates bypass of the infected area with another graft. When the postoperative infection is less acute and manifested only by a slight elevation of temperature and edema of the extremity, therapy should be more conservative. Wide drainage of the bed of the graft and the topical application of neomycin and bacitracin may permit secondary closure of the wound quickly.

The commercial availability of several types of arterial substitutes will undoubtedly have a profound effect upon the structure of vascular surgery. Restriction of blood vessel banks to larger communities and of synthetic grafts to the institutions in which they were developed has necessitated that arterial surgery be performed by a relative few. Someone remarked a few years ago that there were sufficient grafts available but a vascular surgeon was attached to each one! Indeed, the itinerant vascular surgeon has been a natural consequence of this situation. Armed with a brief case full of grafts and a few essential tools he travelled about the country, like the lithotomists of old, bringing his special skills to communities not fortunate enough to have a vascular surgeon—and grafts. No criticism of this practice is implied, however, since historically it has been an essential feature of pioneering efforts in many fields. On the other hand, the availability today of synthetic substitutes at any surgical supply firm portends an early end to this practice. Thus the general surgeon now finds that equipment for performing vascular surgery is within his reach. It remains for him to use it wisely. As has always been true, knowing *when* is as important as knowing *how* to undertake an operation and it is incumbent upon any surgeon with a vascular graft to learn these lessons well.

When the history of surgery during the twentieth century is written the sixth decade will be distinguished by intense interest and significant progress in problems affecting the heart and blood vessels. Among the truly notable achievements will be the development of vascular replacements and the substitution of new arteries for old. To paraphrase the century old aphorism, "A man may be as old as his *new* arteries."

# "CUP-PATCH" TECHNIQUE OF ILEOCYSTOPLASTY FOR BLADDER ENLARGEMENT OR PARTIAL SUBSTITUTION

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THE IDEA of enlarging or replacing the urinary bladder with isolated segments of bowel is not new in urologic surgery. However, Scheele's description (1923) of his "ring plastik" to enlarge the bladder was more or less forgotten until Couvelaire in 1950 initiated the present era of interest in bladder enlargement and partial substitution by isolated loops of ileum.

Various types of ileocystoplasty have been tried and enthusiastically reported by European authors, viz., Cibert, Tasker, Pyrah, Annis, May and associates, Schwartz, Glaser, and Jacobs. Couvelaire's review of the literature, from the time of Mikulicz in 1898, is the best summary of the literature to that time. In 1957, Quenu presented the most recent complete review.

In the American literature, however, there are to date fewer articles concerning this useful operation. Shoemaker and co-workers described experimental and clinical studies in which they used isolated ileac loops, denuded of mucosa and turned inside out, to form seromuscular grafts for bladder and ureteral replacement. This procedure is said to obviate difficulty with mucus formation and electrolyte exchange. Shoemaker's article with Marucci (19) contains a review of the background literature to be found in American journals. Campbell recently described an equivocal success with Shoemaker's technique, but the procedure has not yet found wide acceptance.

Ferris has succinctly reported his success with a patch type of ileocystoplasty (similar to that described by Tasker) in 2 patients treated at the Mayo Clinic.

Our own interest in this problem began in 1953 when animal experiments were initiated to study partial substitution of the bladder with isolated segments of both ileum and sigmoid colon in the dog (22).

To date we have employed ileocystoplasty in 17 patients utilizing a more complex variant of the "patch" technique described by Tasker. The surgical procedures have been technically satisfactory. There has been 1 death from coronary thrombosis. There have been no serious complications related to the surgery. Late results of the procedure are to be described elsewhere.

In the present article the technique is described in detail as we have used it.

## TECHNIQUE ("CUP-PATCH" ILEOCYSTOPLASTY)

The patient is given meticulous bowel preparation for 5 days before surgery. Low residue diet, sulfathalidine, and neomycin for the last 2 days are used. The patient is given only clear liquids by mouth during the 24 hours preceding surgery. Nasogastric suction is initiated the night before or the morning of operation. The abdomen is opened through a lower midline incision. The terminal ileum is inspected; and a

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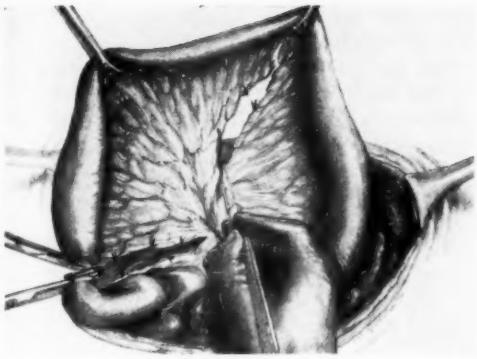

FIG. 1.

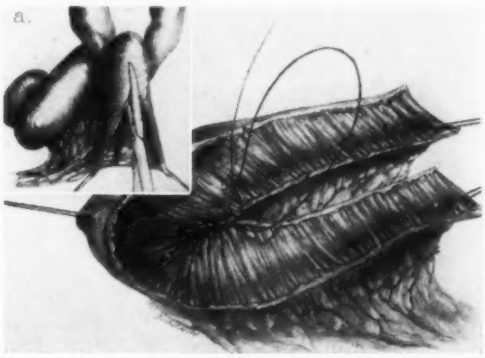


FIG. 3.

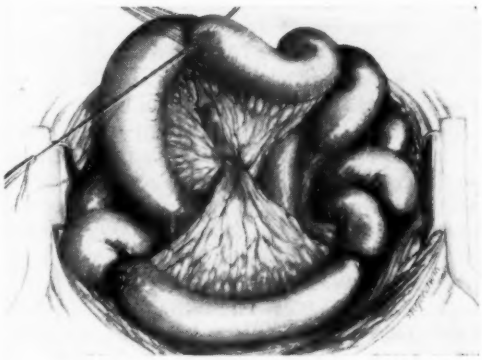

FIG. 2.

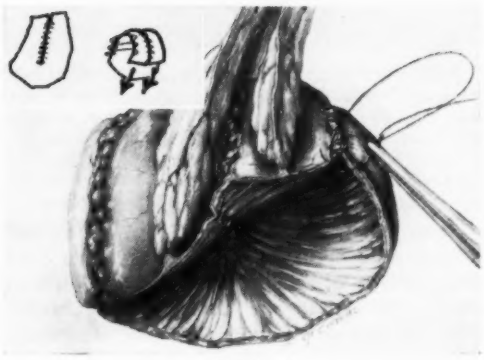

FIG. 4.

FIG. 1. A suitable segment of terminal ileum is isolated with careful attention to preserve its blood supply.

FIG. 2. Normal continuity of the ileum is re-established by ileoileostomy.

FIG. 3. a, After the isolated ileac loop has been irrigated free of intestinal contents, it is opened with scissors by cutting along the antimesenteric border. The flat patch of ileum then formed is pulled together in the form of a U and sutured together with a continuous, intermittently locking No. 000 catgut suture.

FIG. 4. After the U-shaped patch has been formed, it is again sewed on itself from above downward to form a cup-shaped structure shaped like the dome of a bladder.

suitable portion, 20 to 25 centimeters in length, is selected as in Bricker's operation for ureteroileocutaneous anastomosis (Fig. 1). An appendectomy is done.

The ileac loop is isolated with particular care not to destroy any of its blood supply. Normal continuity of the ileum is re-established by ileoileostomy (Fig. 2).

Following this, the isolated ileac segment is partially exteriorized from the wound and methodically irrigated with warm saline solution to remove all mucus and fecal material that may be present in it. Then the segment is opened by cutting along the antimesenteric border with scissors. (Fig. 3a). There is some bleeding from cut edges of the ileum, but this has not proved troublesome.

After the ileum has been opened widely, it is placed in a U-shape; and adjacent margins of the cut ileum are anastomosed to each other by a continuous, intermittently locking, No. 000, chromic catgut suture (Fig. 3). (At first we used curved needles but have found that it is much quicker to use a straight needle in this portion of the "tailoring" of the ileum.) An attempt is made to secure mucosa-to-mucosa approximation of this suture line, but it is not presumed that this will be completely watertight.

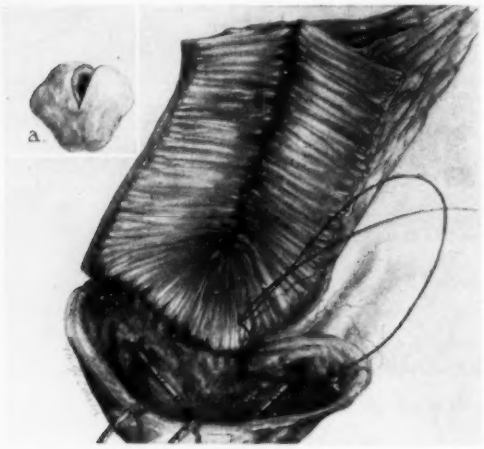


FIG. 5. After the peritoneum has been mobilized from the base of the bladder, the bladder is opened in the midline, through its vertex. The ileac patch is then sewed to the bladder beginning posteriorly in the midline and working laterally from each side using a continuous, intermittently locking catgut suture.

After the flattened loop of ileum has formed a U, it is in some cases curved again on itself from top to bottom to form a "cup" or cap which will fit on the dome of the bladder (Fig. 4). During this portion of the procedure, it may be easier to suture from the outside of the ileum rather than the inside. The same continuous intermittently locking sutures are used.

When this tailoring job is completed, there is a cup or cap of newly formed ileum which looks something like the dome of a bladder and which is ready for anastomosis to the dome of the urinary bladder.

The bladder is gently freed from perivesical tissues. The posterior wall of the bladder is dissected free from the anterior wall of the peritoneum downward toward the cul-de-sac of Douglas, and the bladder is opened in its dome (Fig. 5a). Catheters are placed in the ureteral orifices in order to identify them and prevent ureteral obstruction or damage from subsequent suturing. In some cases the dome of the diseased bladder has been excised; in others, the ileac patch has been sutured directly to the open dome of the bladder. When abnormal bladder is excised, there are two important precautions: The first is not to come too close to the ureteral orifices in the trigone, as this may result in subsequent vesicoureteral reflux and possible ureteral obstruction due to the suture line. The second is to look for the middle vesical arteries which are cut across during segmental resection of the dome of the bladder. They must be recognized, clamped, and ligated meticulously to prevent excessive blood loss.

The ileac "cup" or patch is then brought downward to the back of the bladder, and suturing is begun. Two or 3 accessory sutures from the outside of the bladder to the outside of the bowel are placed to prevent traction on the major suture line. Following this, continuous sutures are placed through all layers of bowel and bladder. Suturing is begun posteriorly in the midline and worked around laterally on each side slowly closing the bladder from above and behind (Figs. 5 and 6).

There may be "dog ears" of redundant ileum which necessitate plastic removal with further closure of that portion of the ileum (Fig. 6).

Before the new bladder is completely closed, it is important to establish perfect catheter drainage. A urethral catheter is placed from the inside outward. (Usually a Malecot catheter is passed to the outside after passing a No. 20 straight red rubber catheter outward and introducing the external end of the Malecot catheter into it and pulling it out through the urethra, leaving the Malecot catheter in good position. Then a No. 30F mushroom or Malecot catheter is placed through a stab wound in the anterior portion of the bladder itself for additional suprapubic drainage. This should *not* be placed through the suture line or through the ileum.

Finally, the bladder is closed anteriorly by suturing the remaining ileum to the anterior and inferior opening in the bladder. This procedure allows a plastic cap of ileum to lie in the dome of the bladder (Fig. 7). A partial attempt is made to extraperitonealize the new bladder using the peritoneum which was mobilized previously. It is sewed loosely to the region of the mesentery of the new ileal bladder.

The prevesical and lateral vesical areas are well drained with multiple Penrose drains.

The abdominal wound is closed in layers and stay sutures are employed. Nasogastric suction is maintained for the first 3 or 4 days during the postoperative period.

The catheters are not irrigated unless it becomes apparent that one of them is obstructed. In this event, gentle irrigations with normal saline are given, never using more than 30

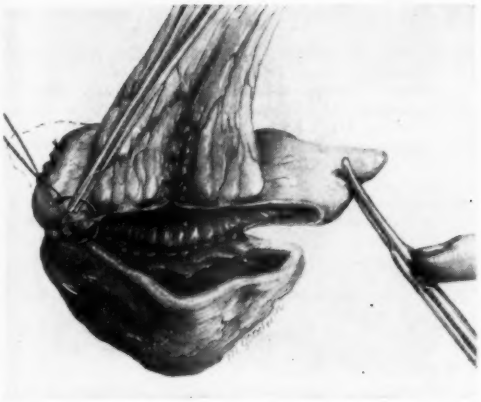

FIG. 6. In some cases redundant portions of ileum have to be excised and tailored to make the flap more cuplike. When this is done it is necessary to close the defects.

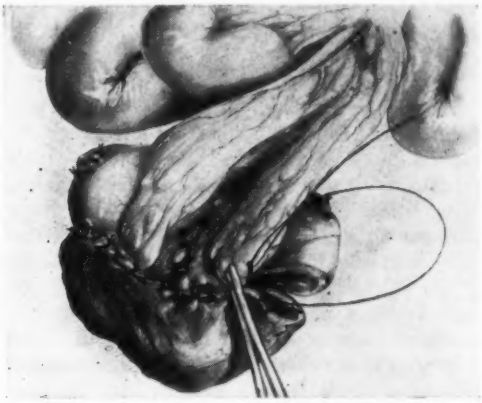

FIG. 7. Finally the ileac cup is pulled downward and sutured to the opening in the dome of the bladder. Before this is done urethral and suprapubic catheters are carefully placed.

cubic centimeters of fluid at a time. It is quite common for one or the other of the catheters to become plugged with thick mucus during the immediate postoperative period, and this is the reason for having 2 catheters. It is presumed that the single continuous suture line would not be watertight if the bladder were distended.

The catheter drainage is maintained for a period of at least 2 weeks. The patient is usually able to resume voiding when the catheters are removed sometime during the third week after surgery.

## RESULTS

Results of our experience will be discussed in detail elsewhere. In 4 patients for whom this procedure was done to enlarge a contracted bladder, functional results have been excellent with good relief of distressing symptoms. Two patients were treated in this way too recently for evaluation. In 4 others this procedure was employed in conjunction with partial excision of the dome of a neurologic bladder in hope of securing a more normally functioning bladder. Only 1 of these patients has had a satisfactory response. Although the operation was technically satisfactory the other 3 patients continue to have inability to empty the bladder. This is presumably due to dysfunction of the external sphincter. In 3 others the new ileac bladder is nonfunctioning (2, permanent because of poor renal function and 1 as a temporary step in treating advanced tuberculosis).

All of the patients have mucus formation. All of them continue to have white blood cells in their urine. Clinical symptoms of urinary in-

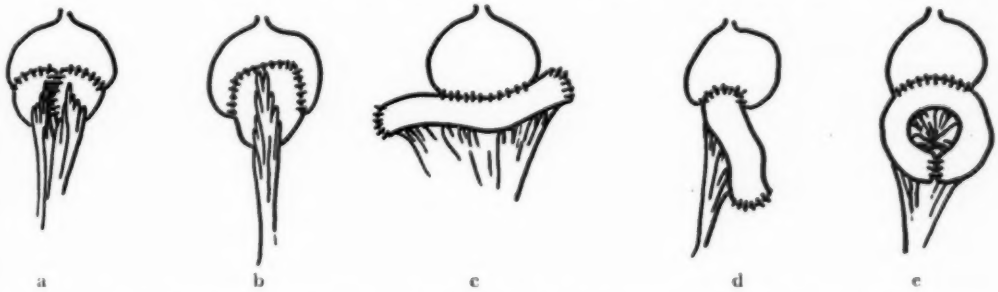


FIG. 8. Types of ileocystoplasty: a, ring plastik (Scheele); b, rat tail; c, U shaped tube (Pyrah); d, flap or patch (Tasker); e, this method, cup shaped patch or cap for new dome of urinary bladder.

fection have not been a problem except in the patients with neurologic bladders.

### OTHER TYPES OF ILEOCYSTOPLASTY

As will be apparent to anyone who reviews the extensive European literature on this subject, individual surgeons have employed various types of ileocystoplasty (Fig. 8). Scheele's original "ring plastik" has found favor with some authors. Others describe success with the "rat-tail" or loop of ileum anastomosed to the dome of the bladder. A few have described success with Tasker's patch. Hanley's work would support our own impression that loops of ileum may tend to act as diverticula during the act of voiding so that patients who have loops of intact ileum used are unable completely to empty the bladder. It is for this reason that we have employed the patch technique. At present, further animal experiments are being conducted to compare various methods. Our encouraging results with these original patients in whom the U-shaped type of flap or patch has been used leads us to wish to continue this technique in cases in which ileocystoplasty is to be employed.

It seems clearly certain that the operation of ileocystoplasty is indicated and applicable for bladder enlargement in patients with contracted bladders. It is doubtful from our experience to date that the substitution of ileum for the dome of a neurologic bladder is suitable except in very few selected cases.

### SUMMARY

Some of the literature concerning various techniques of ileocystoplasty is reviewed. A technique of ileocystoplasty for bladder enlargement or partial replacement is described. In this technique, an isolated loop of ileum is opened and formed in the shape of a U. It is then fashioned into a cup which fits as a cap or cup on the dome of the bladder. Technical steps are described in detail.

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# THORACOABDOMINAL REPAIR OF ESOPHAGEAL HIATUS HERNIA

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EXPERIENCE with over 100 cases of esophageal hiatus hernia treated surgically has proved that the most gratifying repair can be made through the chest. It is true that many of these operations have been performed by using a transabdominal approach, and the results in general have been satisfactory. Nevertheless, for ease of exposure and careful anatomic restitution of the hiatus, transthoracic repair has become our preference.

The great shortcoming of the thoracic approach is inability to explore the abdomen. When many hundreds of asymptomatic diaphragmatic hernias are seen yearly the surgeon realizes that in symptomatic cases, other pathologic states must be carefully excluded. It has been argued that the addition of a counterincision in the dome of the diaphragm permits abdominal exploration. In my experience this type of exploration is inadequate unless a very large aperture is made. This would seem undesirable in the central part of the diaphragm. Further disadvantages of the counterincision have been cited previously (2).

Certainly, the limitations of our most painstaking clinical search for concomitant disease in the abdomen will be conceded by all with experience in this field. These limitations are emphasized by the following cases all encountered in the past 2 years. These reports serve to emphasize the desirability of thorough abdominal exploration.

## ILLUSTRATIVE CASE REPORTS

CASE 1. A patient, aged 56 years, with a history of epigastric distress, pyrosis, and mild dysphagia, was found to have a large, sliding type of diaphragmatic hernia. Gastrointestinal studies were otherwise negative and esophagoscopy showed a moderate degree of esophagitis. A thoracoabdominal exposure was made, and in addition to the hiatus hernia a carcinoma of the head of the pancreas was found. The hernia was repaired and 2 weeks later a pancreatoduodenectomy was carried out.

From the Department of Surgery, The Lahey Clinic, Boston.

CASE 2. After extensive investigation a patient was operated on for what was considered to be a symptomatic, sliding esophageal hiatus hernia. A thoracoabdominal exposure was made. Routine exploration of the abdomen revealed a small mass, about 2.5 centimeters in diameter, in the body of the pancreas. A wide resection of the spleen and the tail and body of the pancreas as far as the inferior mesenteric vein was carried out. Frozen section study revealed adenocarcinoma of the body of the pancreas. This is the earliest lesion of this type that has been encountered at the clinic in a large series of cases of carcinoma of the pancreas. The patient is alive 1 year after operation.

CASE 3. An obese, 48 year old woman was operated on for repair of a diaphragmatic hernia. This hernia was found during the investigation of an obscure secondary anemia. Endoscopy revealed gastritis and esophagitis. A thoracoabdominal incision was made, and routine exploration of the abdomen disclosed a mass in the right ovary. A few weeks later a small cystadenocarcinoma of the ovary was removed.

In view of such experiences and because hernias treated surgically tend to be large or complicated, a thoracoabdominal repair has been evolved. This approach has proved to be satisfactory and has entailed no additional morbidity. There has been no mortality from transthoracic repair in our series up to the present time.

The technique of operation is the same whether the hernia is of the sliding type or the paraesophageal type, which is less common, but more often complicated. It has not been possible to demonstrate to my satisfaction that the latter are truly parahiatal: that is, that the hernia has occurred outside the crural ring. It seems more in accord with my experience to assume that fixation of the medial aspect of the cardia has taken place below the diaphragm with paraesophageal herniation of the body of the stomach.

## TECHNIQUE OF THORACOABDOMINAL REPAIR

*Preoperative preparation.* For the proper evaluation of subsequent complications, preoperative chest roentgenograms and electrocardiograms

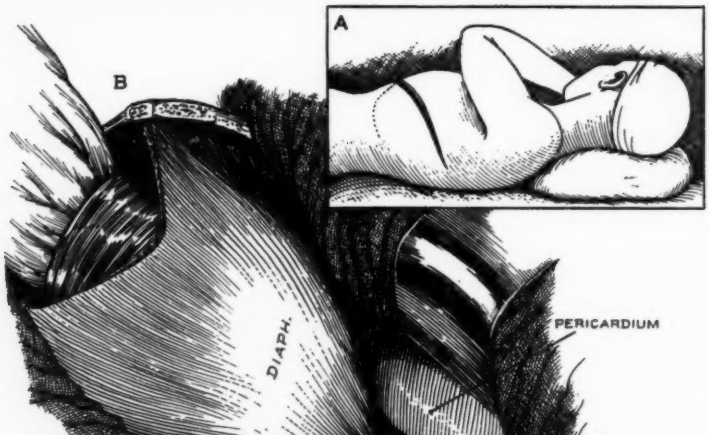


FIG. 1. A, Position on table is almost true lateral (see text). B, Thorough exploration of abdomen and pelvis may be performed. C, With the left hand introduced from below, reduction of the hernia may be maintained and dissection of the sac facilitated. This maneuver affords protection to the delicate esophageal wall, vagus nerves, and opposite pleura.

should be available. Secondary anemia should be looked for and corrected if present. A Levin tube is placed in the stomach unless severe esophagitis is present.

*Position on operating table.* The patient should be placed on the operating table with the left side up in a position that is almost true lateral, perhaps leaning backward very slightly. If possible, the operating table should be of the type that may be tilted at will. The patient's right leg should be flexed acutely at the knee and the hips dropped by breaking the table. These factors are important in securing maximal working room when patients are short and obese.

*The incision.* The incision is made over the course of the eighth rib from the angle posteriorly across the costal margin to a point corresponding to the midpoint of the left rectus abdominis (Fig. 1A). The latissimus dorsi must be cut across. Bleeding points are grasped with fine hemostats, taking small bites of tissue. At this low level in the chest it is possible to spare almost all of the serratus muscle leaving only a fasciculus on the eighth and ninth ribs to guide reapproximation at the conclusion of the procedure. The eighth rib should be resected and the seventh rib divided posterior to its angle. It is important to divide the rib above rather than the rib below because the chest wound at this level tends to spring downward when the spreader is opened.

The intercostal bundles may be divided and ligated to reduce intercostal pain in the postoperative period. The anterior extremity of the incision is carried across the costal margin and, in most cases, about one-half of the rectus muscle is divided. The peritoneum is opened and the chest wound spread with a retractor for

abdominal and thoracic exploration. A satisfactory abdominal exploration may now be carried out. It is important to emphasize the advisability of exploring the thorax also. A left pneumonectomy for cancer was performed on a patient who had had a transthoracic repair of a diaphragmatic hernia a few months previously at another hospital.

*The operative field and initial steps.* When the spreader has been placed, the sac with the inferior pulmonary ligament draped over its upper part will usually be apparent (Fig. 1B and 1C). Since the esophagus may not yet be visible, it is important to have an indwelling Levin tube in place so that this organ may be readily identified by palpation. Furthermore, presence of the tube permits the esophagus to be lifted out of the mediastinum with less danger of opening the contralateral pleura. The pleuroperitoneal sac may then be dissected out of its bed in the mediastinum. If the contents of the sac are reduced into the abdomen and the left hand is introduced into the sac from below, dissection will be facilitated (Fig. 1C).

It is important at this point to avoid trauma to the vagus nerves. When the sac has been freed down to its attachment to the stomach wall, it may be opened. If it is large, it may be excised and the defect closed. Intimately associated with the sac is the pleuroperitoneal and fascial reflection which extends from the surface of the diaphragm to the lower esophagus. This structure, the phrenoesophageal ligament, may be sutured to the under aspect of the diaphragm. It is well to include a small bite of gastric wall in each suture to restore and maintain the proper position and angulation of the cardia. It is sometimes difficult to understand how this flimsy structure, the phrenoesophageal ligament, can carry out the important function which is ascribed to it. On the contrary, in my opinion, restoration of normal anatomic relationships and precise repair of the hiatus are of greatest importance. The following technique is based on this belief.

*Steps employed to secure relaxation of the hiatus.* At this stage in the operation certain steps have been found useful in permitting greater relaxation of the margins of the defect. The tissues comprising the hiatus are characteristically weak and friable; thus, the basis of a secure repair must be total absence of tension. The field should be prepared so that the sides of the

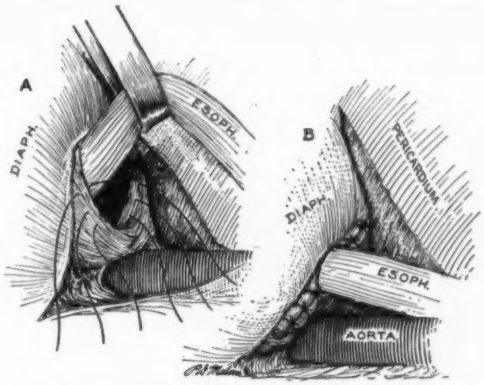


FIG. 2. A, Attention is called to the following: (1) Reduction has been completed. (2) Sac or sac remnant has been sutured to the under surface of the diaphragm. This may be done under direct vision through the abdominal component allowing inclusion of the gastric wall in these fixation sutures. Direct vision placement also avoids injury to the large inferior phrenic vessels. (3) Bare area on the heart represents separation of normal fixation between pericardium and diaphragm. (4) Bare area on the aorta represents mobilization of right crural margins from aorta. This is most important in relaxing the hiatus and providing maximum exposure. (5) Finally the pleura in the gutter is incised around the chest wall at its point of reflection. B, The completed repair. Note the bare area on the pericardium and aorta.

hiatus actually fall together and lie in apposition before the sutures are placed.

Anatomic study of the diaphragm has suggested that the hiatal edges are held apart by opposing forces: namely, fixation of the periphery of the diaphragm to the parietal chest wall and fixation of the diaphragm to the pericardium. Further study suggested that some freedom from tension in the hiatal area might be achieved by undermining the attachment of the diaphragm to the pericardium (Fig. 2A). This procedure proved to be simple to perform, limited only by the presence of the phrenic nerve anteriorly. If these structures again fuse, which seems likely, it probably will not occur faster than healing of the repaired hiatus.

Since it is an anatomic fact that the reflection of the parietal pleura in the costophrenic angle is higher than the actual costophrenic muscular attachment, it seemed reasonable to incise this pleural reflection from the gutter around to the lateral chest wall.

The degree of relaxation of the hiatal area of the diaphragm which these simple measures

provided was impressive. Upon retracting the dome of the diaphragm downward with this superior exposure, a greatly improved approach to the hiatus was obtained. It was then apparent that the margins of the right crus were still fused to the aorta. Therefore, a third relaxing maneuver was added. This consisted of freeing the tissue down to the aortic aperture (Fig. 2A and 2B). At this point, when the dome of the diaphragm is held down with a retractor, the entire hiatus and surrounding area of the diaphragm are clearly visible (Fig. 2A).

*Repair of the hiatus.* The margins of the hiatus will now fall together and, as has been suggested by Allison, only a few sutures are required. Nevertheless, with this improved relaxation and exposure it is possible to buttress the first layer with a second row of 3 or 4 sutures. The repair should be carried out around the esophagus in such a way that this organ lies deep in its natural bed in the mediastinum. At the conclusion of the repair, it should be possible to pass the finger snugly alongside the esophagus into the abdomen.

*The closure.* The initial step in closing this combined wound is reapproximation of the costal margin. One or 2 sutures of chromic catgut on a cutting needle are used. A catheter is placed in a dependent position in the chest and stitched to the parietal pleura so that it lies in the gutter close to the cavity in the mediastinum. The latter cavity is not closed. Sometimes 1 or 2 through-and-through tension sutures of heavy silk are utilized in the abdominal component of the incision. The remainder of the abdominothoracic incision is closed with interrupted catgut sutures. In recent years I have not crushed the phrenic nerve, believing that the reduction in vital capacity caused by this maneuver is undesirable. Madden's suggestion that the nerve be injected with procaine seems admirable. This injection is made just before the pleura is closed. It may help to prevent strain on the suture line during the restless postanesthetic period.

*Postoperative care.* The Levin tube is kept on suction for 48 hours, or until it is established that gastric tone has returned and pylorospasm is not present. It is important to avoid dilatation of the stomach in this early period. When it is certain that the stomach is emptying properly, the feeding schedule may be greatly accelerated.

## SUMMARY AND CONCLUSIONS

Experience with the repair of diaphragmatic hernia has proved that in cases of large or complicated hernias the thoracoabdominal approach is the most satisfactory and does not entail any additional morbidity.

Certain details of technique have been evolved during this experience, and these have contributed to the ease and satisfaction of repair.

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# AN ANORECTAL PLASTIC OPERATION FOR FISSURE AND STENOSIS AND ITS SURGICAL PRINCIPLES

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THE ANORECTAL OPERATION for fissure in ano and anal stenosis, to be described, is an original and successful procedure that has been used routinely for the past 11 years. It differs quite radically from other operations for anal fissure or stenosis, and the merits of this plastic procedure are demonstrated by the ease of technique, the relative freedom from postoperative pain, rapidity of healing, and almost complete absence of postoperative complications.

Whereas the operation may be used for stenosis or stricture without fissure, it should not be used for early fissure, fissure during pregnancy, or fissure of infancy, since it has been shown that these conditions usually respond to nonsurgical measures (1, 2, 3). On the other hand, chronic fissure in ano, especially when associated with anal narrowing, variously termed anal stenosis, anal contracture, or stricture, is a surgical condition that the usual operative procedures frequently do not correct, since they are apt to result in painful spastic wounds lacking normal expansile and contractile properties. There also may be the added difficulty of controlling the bowel function due to the scarred and deformed anal passage and the frequent accompanying condition of an irritable dysfunctioning colon. The distinctive pathologic condition present may be characterized by an inflamed anal fissure or ulcer, infected anal duct or gland, inflamed and shrunken anal epithelium, and a diffuse fibrotic or scarred and narrowed anal orifice. Excision of such diseased tissue may result in an excessively denuded area, abetted in part because the degree of exposed and denuded area of excision mechanically parallels the degree of contracture present (Fig. 1). Obviously the normal function and healing of such wounds are difficult to obtain under such circumstances, thus indicating the need for this anorectal operation.

All anorectal surgery should be governed by numerous rules or principles of technique and management such as: securing adequate room in the anorectal passage, removing all diseased anorectal tissue, leaving adequate islands of anodermal tissue and anorectal mucosa, transposing or leaving tissue in its normal anatomic position, and especially providing careful preoperative and postoperative treatment and management. Additional rules may be distinctive for specific types of anorectal disease. For example, an anorectal abscess obviously requires different surgical treatment, technique, and management than does a fistula because of the specific surgical principles by which each is governed. In fact, if the principles of treatment that apply to specific types of anorectal disease are not followed, faulty healing or malfunction may result. Specific principles of treatment also apply to anorectal surgery for fissure and stenosis, since, as stated, the distinctive pathologic condition of infection, scarring, and inflammatory spasm and contracture may leave painful, widely exposed nonelastic anorectal wounds when nonplastic procedures are used. The anorectal plastic operation, to be described, covers an otherwise open and denuded area of excision and secures a normally expansile and contractile anorectal orifice with subsequent rapid return to normal anorectal structure and function.

Plastic surgery is defined in a medical dictionary as "restorative surgery of lost parts or the repair of defects by grafting . . ." (4). The operation to be described conforms to a definition of anorectal plastic surgery which we may specifically define as any such procedure that corrects an anorectal defect by tissue transplantation to secure thereby more normal anorectal function. It also conforms to and illustrates specific rules of treatment and management of anorectal plastic surgery, which, differing from those of nonplastic anorectal surgery, permits wider areas of anorectal dermal and mucosal excision and does not necessitate wide radial drainage at these areas, since grafts are laid across such defects. In addition, great care is required, as it is in all plastic surgery, for the preparation of the flaps. Incisions should be made along the lines of

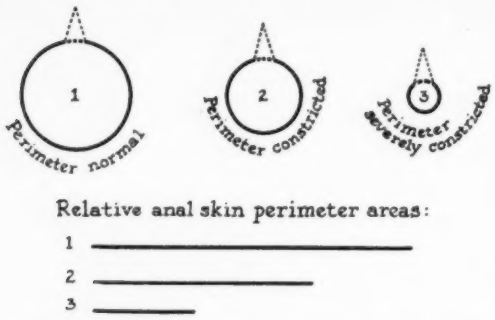


FIG. 1. Demonstrating relative degrees of tissue denudation following excision in anal stenosis.

cleavage parallel to radially coursing blood vessels, with caution to avoid excessive undermining of the flap itself; undue tension must be avoided; exacting hemostasis must be secured; fine sutures, needles, and forceps must be used; and the tissues must be handled delicately to avoid necrosis of the graft. These latter precautions are generally agreed upon in all types of plastic surgery.

TECHNIQUE OF OPERATION

The reverse Trendelenburg position is used. The anus and field of operation are exposed by the use of a modified Bearse taping. Two strips of elastoplast tape are attached to each buttock, stretched laterally, and their ends fixed anteriorly (Fig. 2A).

*Posterior midline incision and tissue excision.* A posterior midline incision is made from the anal orifice halfway to the coccyx and continued intra-anally to just above the posterior anorectal line or dentate margin (Fig. 2B). When a fissure, tag, papilla or papillae, external sinus, or scar is present posteriorly, the incision is extended within narrow limits on either side, to include the diseased tissue by excision, and superiorly is fanned out slightly, to obtain crypts and mucosa just lateral to the posterior midline. When an anterior or lateral fissure exists, it is removed later by an excision which also includes hemorrhoidal tissue if present at the site of fissure or immediately adjacent. If stenosis exists without postanal inflammatory disease, such as tag or fissure, a simple posterior midline incision is performed without excision of postanal epithelial tissue. The posterior midline incision is then carried partially through the subcutaneous external sphincter, through the decussating fibromuscular fibers from the conjoint longitudinal muscular septum, and through the corrugator cutis fibers attached to the skin. Superiorly, bands of the internal sphincter are exposed and partially severed. The degree of partial incisional severance is carefully gauged by the size of expanding dilatation obtained, which should be an exposure diameter of about 4 centimeters.

*Posterior mucosal mobilization and excision.* The normal purse-stringing of the mucosa into the folds of Morgagni permits lateral spread of the midline mucosal incision as the anal passage is dilated by speculum and midline incision. A width of some 3 centimeters is picked up and mobilized by blunt dissection in its increased areolar plane of cleavage. It is then transversely fixed with a hemorrhoidal clamp about 1 centimeter below the point of mobilized dissection (Fig. 2C). All crypts and papillae are excised, and anal ducts or glands are thereby laid open or excised.

*Skin flap mobilization.* A radial puncture wound is made 3 to 4 centimeters beyond the anal margin on the right and left posterolateral areas (10 and 2 o'clock). Subcutaneous incisions by scalpel are carried through the puncture wounds to the midline wound to within 2 centimeters of its coccygeal end, over both the internal and subcutaneous external sphincters, and finally, to the upper pole of the wound superior to the dentate margin (Fig. 2D). The point and blade are directed nearly radially and separate subcutaneous incisions are made, care being taken not to mobilize the flap completely for fear of damage to its blood supply. Perianally, mobilization includes subcutaneous fat, but anally and intra-anally no fat is present and the incision is made through the areolar tissue with severance of the corrugator cutis fibers from the conjoint longitudinal muscular septum, and some fibers from both sphincters. Continued bleeding rarely occurs and can be controlled by incision and subcutaneous suture ligature. Free exit of serum and blood prevents hematoma formation. Skin discoloration from suggillation may occur but disappears within 6 to 10 days.

*Suture of plastic flap and mobilized mucosa.* Right and left posterolateral suture of skin and mucous membrane is begun at each outer angle of skin and mucosal juncture (Fig. 2E) with No. 00 silk. A carefully placed Lembert suture of mucosa is taken, followed by a relatively large bite of anal skin. Three sutures may suffice on either side,

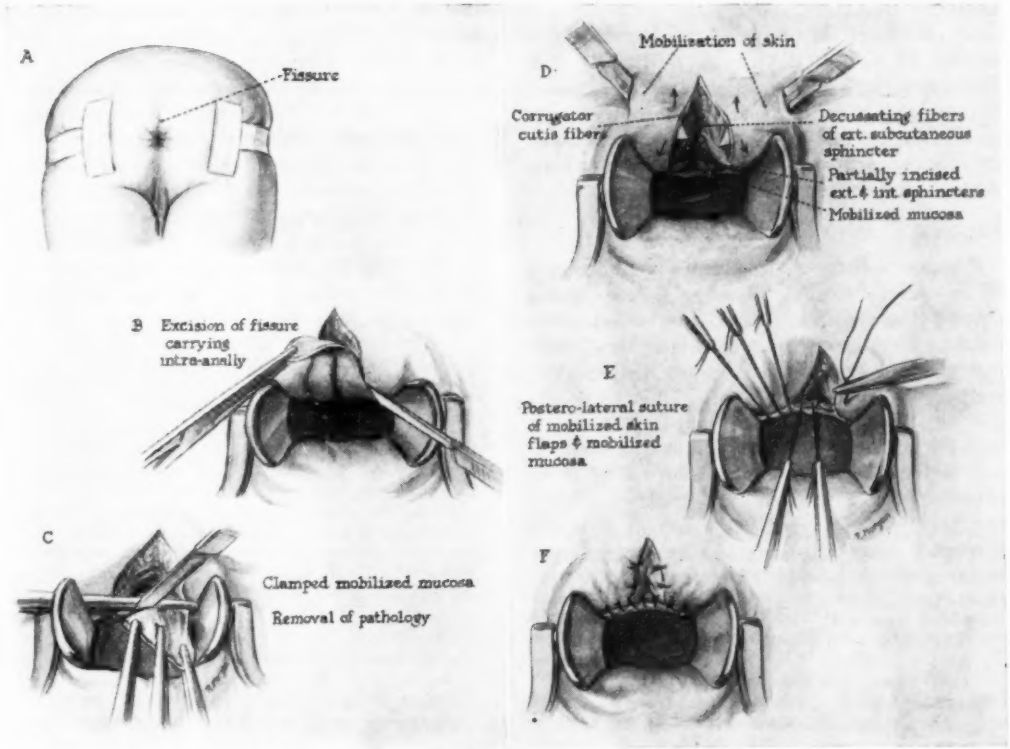


FIG. 2. A, Reverse Trendelenburg position with modified Bearse elastoplast exposure. B, Excision of diseased tissue, including crypts, fissure, scar, and mucosa. C, Excision of same superior to dentate margin. D, Mobilization of skin perianally, also showing partial posterior sphincterotomy. E, Suture with silk of mobilized skin and mucosa with catgut at dentate margin level. F, Completed plastic operation with clamp ligature hemorrhoidectomy to follow.

provided that the posterior gaping wound is fairly well closed, except for a midline strip of open wound. Each successive suture is placed close to the last mucosal suture, but relatively much farther apart and outward on the skin. Interrupted intervening, through and through, sutures of skin and mucosa may be taken if bulging or lipping is present with an inexact approximation of tissue. One or 2 external sutures of skin to the wound are taken near the midline postanally (Fig. 2F). These sutures are intentionally tied tight to permit their delayed slough within 4 to 8 days and, thus, removal of all such sutures is not necessary at a later time. Suture of free mucosa with No. 00 atraumatic catgut by interrupted Lembert sutures is then taken at or slightly above the dentate margin level.

*The hemorrhoid operation.* Hemorrhoidectomy should be performed, preferably, by clamp and ligature. Radial clamp ligature excision when necessary, and particularly anorectally on the right and left posterolateral and right anterolateral areas (10, 2, and 5 o'clock), benefits the wound since it assures better balance, tension, and symmetry of the tissue throughout. Imbrication must be avoided on the right and left posterolateral areas at the inner angle of the flap where the tissue is inclined to bulge slightly.

## RESULTS

All patients treated, numbering several hundred, had excellent postoperative and final results. Complications were practically nil; except for a slight necrosis of skin flaps occurring in a few of the early cases. Pain has been limited to the day of surgery and, with the usual post-

operative treatment, found to be comparatively mild or absent. Healing was usually complete within 18 to 21 days, and frequently less. Check-ups, with a few exceptions, were carried out for a 6 months' period and showed anorectal function to be normal. The exceptional delayed healing occurred from other causes, such as diabetes or fungal infection.

SUMMARY

The absence of complications and the normalcy of anorectal function following the operation described are explained on the following basis: Healing is rapid since there are only thin linear wound strips which require epithelization. Pain is minimized by covering with a flap an otherwise painful area, by partial denervation through undercutting of the flap, as well as by its infolding, which tends to hold the anal orifice from painful spasm. Undercutting overcomes fibrosis and restores the supple function of both skin and anorectal structure. Only the inner anal epithelium, which gradually becomes thinner and finally columnar as it approaches the anorectal line, is used intra-anally by this method of an infolding flap. These are the factors which restore normal anorectal tissues and function, thereby preventing complications. The operation demonstrates its conformity to the surgical principles governing anorectal plastic surgery. The limitations of nonplastic operations for fissure or stenosis are in themselves the indications for using the anorectal plastic operation described.

This original and successful anorectal plastic operation for fissure in ano and anal stenosis is a marked improvement over the usual nonplastic operation.

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# THE SURGEON'S LIBRARY

## *Reviews of New Books*

A LARGE NUMBER of interesting and very well presented articles are compiled in Volume IX of *Archivio "Putti"*.[1] This volume is testimony to the steady advances of modern Italian medicine. Most of the articles deal with clinical orthopedic subjects and the authors show a sound grasp of the topics.

Mangani and Laus discuss compression of the median nerve at the wrist or syndrome of the carpal tunnel. Thirty-five patients were studied, and 25 were operated upon. The lesions observed in the median nerve are beautifully illustrated in color. The syndrome was more common in women than in men in the proportion of 2½ to 1. The average age of the patients was 53 years. Their occupation usually involved heavy domestic labor. The lesion was observed in 11 women and 2 men who had tenovaginitis of the carpal flexors. In 11 women and 5 men, the only lesion found was an enlargement of the median nerve at the level of the proximal margin of the transverse carpal ligament and flattening of the nerve underneath the ligament. The symptoms observed were paresthesias and pain along the median nerve distribution and weakness of the thenar muscles. Surgical treatment was advised except in very early cases with minimal symptomatology. The transverse carpal ligament was divided at the time of operation. Of the 25 patients operated upon, the results were very good in those operated upon before reaction of degeneration in the thenar muscles developed. In another article Mangani presents beautiful radiograms showing the profile view of the carpal tunnel. For this view, the anterior aspect of the forearm rests over the casette, and while the hand is hyperextended the x-ray tube is placed at an angle of 45 degrees with the casette.

Fineschi presents 2 cases of polyostotic fibrous dysplasia with some areas in the skeleton resembling bone seen in Paget's disease. No phosphatase blood values are given.

Stringa and collaborators present statistical results in fractures of the humerus, forearm bones, femur, and tibia in adults treated at the Instituto Ortopedica Toscano where conservative treatment is preferred. Fractures of the humerus are treated by immobilizing the arm in a shoulder plaster cast after reduction. One hundred and thirty-four diaphysial fractures of the humerus united in an average of 62 days; in 10 cases solid bony union did not occur until 100 to 220 days after the fracture; only 1 instance of pseudarthrosis was observed. Ninety-six fractures of the forearm in adults were reduced either by manual traction (67 per cent) or traction through a Kirschner wire (13 per cent) applied through the distal portion of the ulna and radius. In some cases a Kirschner wire was also applied through the olecranon for counter traction. In 20 per cent of the cases, an open reduction was necessary. Bony union occurred in an average of 89 days except in 9 cases in which more than 120 days were required. Four of the 9 delayed unions were observed in cases of open reduction. There were 14 per cent of failures. In 3, there was pseudarthrosis of the ulna; in 1, pseudarthrosis of both bones; in 5, a radioulnar synostosis developed, and 1 patient had ischemic paralysis.

The fractures of the femoral shaft were treated by skeletal traction, usually with a Kirschner wire through the lower end of the femur for a week; the patient was then placed in a plaster hip spica with the Kirschner wire included. The hospital stay of these patients was very short as they went home shortly after the cast application. Two hundred and seventeen femoral shaft fractures in adults are reviewed. Only in 2 compound fractures was an open reduction done at the time of the cleansing and debridement of the wound. Three other cases necessitated an open reduction 10 to 15 days after the fracture. Four patients died during the hospital stay. Death was due to cardiorespiratory difficulty in 2 cases, and to shock in the other 2 instances. In 4 cases, amputation was necessary due to extensive wounds with division of the femoral artery. The fractures united in an average time of 91 days, and there was a single instance of nonunion in a double fracture. The results in these cases are certainly excellent although limitation of motion of the knee following treatment was very common. Probably the knee joint stiffness could be decreased if the Kirschner wire were applied through the tibia instead of the femur and if the plaster immobilization were less prolonged.

Six hundred and eighty-four adult patients with fractures of the leg were studied. Sixteen per cent were treated by immediate manual reduction and plaster cast immobilization. In 83.6 per cent, skeletal traction with a Kirschner wire through the os calcis was used for 4 to 6 days, and followed by the application of a long leg plaster cast with the Kirschner wire left incorporated in the plaster. This cast was left on for 45

[1] ARCHIVIO "PUTTI" DI CHIRURGIA DEGLI ORGANI DI MOVIMENTO. Bibliografia 1955. Directed by O. Scaglietti. Edited by L. Gui. Vol. IX. 460 pages, illustrated. Firenze: Edizioni Scientifiche dell "Instituto Ortopedico Toscano," 1957.

to 60 days. In 2 cases (0.4 per cent), open reduction was necessary. There were no fatalities. In 2 cases amputation was done because of damage to the main vessels of the leg. The fractures healed in an average time of 105 days and there were 9 pseudarthrosis (1.6 per cent). These statistics of results in the conservative treatment of fractures should be of interest to American surgeons who favor open reductions, and with results usually far less satisfactory than the results obtained by simple conservative means.

Canepa writes a learned article on the use of metallic springs for substitution of paralyzed muscles. He operated on dogs, replacing the quadriceps and the gastrosoleus. One difficult problem that the surgeon has to cope with is the determination of the strength of the spring. Another problem is the intolerance of the soft tissues of the host for a moving foreign body.

Monesi and Brodetti present detailed radiographic studies of the spinal canal after lipiodol injection. Pagni adds another article upon the differentiation of intraspinal tumors and cysts by myelography.

Stringa implanted small methylcellulose cylinders containing 100 units of growth hormone in the tibia and fibula of rabbits adjacent to the actively growing epiphysial plate near the knee. Control polyethylene cylinders were used in another series of animals. In both the control and experimental animals there was increase in width of the epiphysial plate at first but no specific action of the growth hormone was observed. The growth hormone was obtained from Middlesex, England, but it is not stated from what animal it was extracted.

The circulation of amputation stumps was studied by Baldini and Pagano by means of arteriography, oscillometry, photoplethysmography, and skin thermometry. A diminution in the size of the large arterial trunks was observed concurrently with the establishment of a collateral circulation. There was also a diminution of the amplitude of the oscillometric waves as compared with the normal side.

A very important article on intervertebral disc infections in children is presented by Calandriello and Palandri. A primary infection of the intervertebral disc in the lumbar area is described in 12 children, most of them under 6 years of age. The authors believe that the frequency of infections of the intervertebral disc in children is due to the abundant blood supply of the disc in comparison with the adult, in whom the blood supply becomes very scarce and even disappears and disc infections are very rare. The symptoms consist of mild pain and stiffness in the spine of slow onset; the roentgenograms reveal a progressive decrease in the width of the intervertebral disc followed later by slight sclerosis of the marginal bone. The treatment was bed rest and antibiotics. This form of infection is of mild character and the healing time is shorter than in spondylitis.

Calandriello describes 2 cases of calcification of the cervical intervertebral disc in children who were successfully treated with prednisone. The patients had pain and stiffness of the neck of acute onset but no fever.

Nigrisoli reports upon 3 cases of pseudarthrosis of the clavicle in infancy. Only 1 clavicle was involved and there were no other signs of cleidocranial dysostosis. These cases probably represent birth fractures in a congenitally defective clavicle.

Pietrabissa studied traumatic epiphysial separations in children. The author includes in the article slipped epiphyses of the upper end of the femur in children with defective epiphysial plates and the traumatic separations of many other epiphyses (lower end of the femur, upper humerus, lower radius, and ankle) which occur in normal children following severe trauma. He studied traumatic separations occurring in experimental animals and observed that the separation occurs through the metaphysis in the area of calcification of the cartilage.

Grilli and Minervini reported on tuberculosis of the knee treated with streptomycin, isoniacid, and PAS together with bed rest and immobilization. The synovial forms of tuberculosis with minimal or slight skeletal involvement usually heal with preservation of motion. The authors advise early biopsy in doubtful cases. In 129 patients followed with sufficient clinical and radiographic data, 44 had an advanced type of skeletal tuberculosis. Orthopedic and antibiotic treatment administered to these patients brought about spontaneous ankylosis, bony or fibrous, in 6 cases. Thirty-eight patients had to have resection arthrodesis of the joint. The remaining 85 patients had slight synovial or skeletal knee joint tuberculosis. They were treated also by immobilization and antibiotics. In 48 cases, the lesion healed with preservation of motion. In 37 cases, the evolution was toward fibrous or bony ankylosis. Of the 48 patients in whom the lesion healed with preservation of motion, 31 had a pure form of synovial tuberculosis and 17 had slight skeletal involvement. From their study the authors conclude that tuberculosis of the knee can heal with motion if treatment is started a few months after the onset of the disease, if it does not have a destructive tendency, and if the immobilization of the knee has not been too prolonged. —*I. V. Ponseti.*

THE THIRD TOME (in 2 fascicles) of Professor Paturet's *Traité d'anatomie humaine*[2] is now available. These textbooks follow 2 earlier and equally impressive tomes, covering together the anatomy of the skeleton, articulations and muscles, and of the upper and lower extremities.

The additional volumes contain over 1,300 pages and 756 figures (additive to 1,329 figures in the antecedent volumes); they deal with venous and visceral anatomy.

The *Traité* is so grand in scope and so detailed in presentation, both textual and pictorial, that a review must be limited to sampling of its encyclopedic content. The venous sinuses of the dura mater and their accessory veins will serve in this capacity.

This part of the account covers 30 pages, includes 17 illustrations, most of them semischematic, all of them brightened with color overlay. Initially, the general nature of the cranial sinuses is discussed, next their external form and internal configuration, then their lacunar communication and confluent portions

[2]TRAITÉ D'ANATOMIE HUMAINE. By G. Paturet. Tome III. Fascicule I. Appareil circulatoire (a l'exclusion des veines). 663 pages, 402 illustrations. 11,000 fr. Paris: Masson et Cie, 1958.

(with information on variations). Following this introductory presentation, each sinus is discussed *in extenso* under the familiar headings of morphologic interest. Relationships are stressed, particularly those of surgical significance. The accompanying illustrations depict anatomic aspects—skeletal, arterial, neural, and meningeal. Some of the figures record the form and position of vitally important, but customarily disregarded, structures. One such illustration demonstrates the endolymphatic sac, shown dissected from its dural investment on the posterior surface of the petrous part of the temporal bone.

The French text can be read handily, but the employment of common names in the labels (in place of the standard BNA terms) could constitute an unfortunate barrier to our medical students and doctors. However, so manageable is this barrier when compared with the reward which awaits the linguistic hurdler, that Professor Paturet's imposing series may be unhesitatingly recommended to those who are willing to work for expansive knowledge of the structure of the human body. —*Barry J. Anson.*

THE MONOGRAPH, *Klinische Calorimetrie und Thermometrie*,[3] presents a detailed analysis of the physical measurement of skin and tissue temperature. The physiologic bases of animal heat and its regulation are carefully reviewed. The mechanisms for disturbances in temperature regulation are mentioned. The technical details of apparatus for measuring and the method of its use are clearly presented. The special portion of the monograph includes the use and significance of thermal measurements in clinical practice with detailed descriptions of test methods and functional tests. Special applications in surgery, internal medicine, dermatology, anesthesiology, hypothermia, extracorporeal circulation, and obstetrics and gynecology are given. The text is carefully written, and the paper and illustrations are of excellent quality. The Teutonic bibliography gives a thorough review of the field and includes many recent Anglo-Saxon articles. This monograph is recommended to all who are interested in clinical measurements of tissue temperatures.
—*David H. Watkins.*

ONCE AGAIN James T. Case[4] has made it possible for those of us who do not read German easily to take advantage of the best of the German literature on diagnostic roentgenology. The translator's modest comment in the foreword that this has been a "labor of no inconsiderable proportions" is, I am sure, a gross understatement. The text "reads" beautifully.

This work is intended as a supplement to the 4 volume treatise *Roentgen-Diagnostics* translated by James T. Case and published by Grune and Stratton in 1952, and is a compilation of recent advances in certain diagnostic fields for the years 1952 to 1956. Dr. Case has extended the bibliography to include references appearing as late as the last quarter of 1957. The presentation of material in this new volume follows the same pattern as the previous ones with, for the most part, different authors for each chapter.

The topics include Protection from Radiation Injury in Diagnostic Roentgenology; Recent Advances in Diagnosis of the Spine; Benign and Semimalignant Cystic Bone Tumors; Roentgen Evaluation of the Cardiac Function in Adults; Angiocardiography of Congenital Anomalies of the Heart and Great Vessels with Right to Left Shunt; Abdominal Aortography; Arteriography of the Extremities; Venography; Vertebral Artery Angiography; Diagnosis and Differential Diagnosis of Diseases of the Pulmonary Stroma; Inflammations and Dystrophies; Vanishing Lung; The Middle Lobe Syndrome; The Small Gastric Cancer; Benign Hypertrophy of the Pylorus in Adults; Prolapse of the Gastric Mucosa; Tumors of the Small Bowel; Nonsclerosing Ileitis; Diagnosis of Colonic Polyps; Pneumoretroperitoneum and Pneumomediastinum; Cholangiography with Biligrafin; Operative Cholangiography and Hysterosalpingopelvigraphy.

The roentgenograms are reproduced in the fluoroscopic image and are of excellent quality as are all the line drawings, photographs, and other illustrations. The printing, which is excellent, was done in Germany.

Anyone having the 4 volume treatise should consider this Progress Volume I a must. All diagnostic roentgenologists and physicians interested in roentgenology will find this an outstanding source of the newer ideas from abroad, as well as those originating in this country. —*R. Burns Lewis.*

THE BOOK entitled *The Practice of Nuclear Medicine*[5] by Blahd, Bauer, and Cassen concerns the medical use of unstable isotopes, including some theoretic physics, but throughout its 4 parts and appendix there are many useful clinical adjuncts. These 4 divisions deal with physical principles, diagnostic methods, therapeutic applications, and laboratory and nuclear instruments. In these parts are discussed the treatment and diagnoses of many diseases, under each isotope.

The bibliography is extensive and follows each chapter in its part. There is an excellent introduction on the historical development by Paul C. Aebersold.

Much of this work has been published in separate articles, but this book brings the essence of nuclear medicine together in the very readable volume. Because of its completeness it is a must for every physician. —*J. E. Kearns.*

THE SECOND EDITION of the *Physical Examination of the Surgical Patient*[6] is again a book devoted to diagnostic procedures and technique. Thus, it assists the student or clinician "to discover the presence and extent of injury or disease." Although mention is made of spe-

[3]KLINISCHE CALORIMETRIE UND THERMOMETRIE. Die thermischen Mebverfahren zur Registrierung der Haut-und Gewebedurchblutung am Menschen Grundlagen, Technik Methodik, Anwendung in Klinik und Praxis. By Dr. Helmut P. Kuemmerle, with foreword by Prof. Dr. M. Ratschow, F.A.C.A. 112 pages, 52 illustrations. $4.30. Stuttgart: Georg Thieme, 1958.

[4]ROENTGEN-DIAGNOSTICS. By H. R. Schinz, R. Glauner, and E. Uehlinger. Translated from the German by James T. Case, M.D., D.M.R.E. (Cambridge). Vol. I. 623 pages, 892 illustrations. $35.00. New York and London: Grune & Stratton, Inc., 1958.

[5]THE PRACTICE OF NUCLEAR MEDICINE. By William H. Blahd, M.D., Franz K. Bauer, M.D., and Benedict Cassen, Ph.D. Foreword by Joseph F. Ross, M.D. 407 pages, 111 illustrations. $12.50. Springfield, Ill.: Charles C Thomas, 1958.

[6]PHYSICAL EXAMINATION OF THE SURGICAL PATIENT. By J. Englebert Dunphy, M.D., F.A.C.S., and Thomas W. Botsford, M.D., F.A.C.S. 2nd ed. Philadelphia: W. B. Saunders Co., 1958.

cific diagnostic tools, most of the book is devoted to bedside techniques.

Specific diagnostic procedures are discussed with emphasis on the regional examination of the patient. Consequently, one finds a chapter devoted to the elective examination of the head and neck, the chest, the abdomen, inguinal-femoral regions, and the extremities. Important findings to be noted by means of inspection, palpation, percussion, auscultation, and in some instances also by x-ray or fluoroscopic examination are given. Abnormal findings which might be noted upon examination are summarized and evaluated. There are only brief references to distinct pathologic conditions or diseases and, as such, this book cannot be interpreted as a textbook of surgery.

Chapters which have been added since the previous edition include those on history taking and the special examination in the detection of cancer. There is, in addition, general revision of the textbook and throughout it is well illustrated. Of value is the division of the book into two component parts; one, the elective examination of the patient and the other, the emergency examination. Both of the sections will serve ably.

This book will be of assistance in the examination of any patient. The clarity of presentation, adequacy of material, and coverage of the subject makes this an especially valuable book for the student and for the house staff officer, although practicing physicians alike will also appreciate its value.

—*W. Harrison Mehn.*

## BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgement must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

Anatomy for Surgeons. Vol. III. The Back and Limbs. By W. Henry Hollinshead, Ph. D. 901 pages, 785 illustrations. $23.50. New York: Hoeber-Harper, 1958.

Emergency Childbirth; a Manual. By Gregory J. White, M.D. 63 pages, illustrated. $3.00. Franklin Park, Ill.: Police Training Foundation, 1958.

Essentials of Human Reproduction; Clinical Aspects, Normal and Abnormal. Edited by Joseph Thomas Velardo. 270 pages, illustrated. New York: Oxford University Press, 1958.

The Birth of Normal Babies. By Lyon P. Strean, M.Sc., Ph.D., D.D.S., F.A.P.H.A. 194 pages. $3.95. New York: Twayne Publishers, 1958.

Staphylococcal Infections. By Ian Maclean Smith, M.D., Ch.B., F.R.F.P.S.G. 180 pages, 6 illustrations. $4.25. Chicago: The Year Book Publishers, Inc., 1958.

Temporal Lobe Epilepsy. Edited by Maitland Baldwin, M.D., and Pearce Bailey, Ph.D., M.D., and Cosimo Ajmone-Marsan, Igor Klatzo, and Donald Tower. 581 pages, illustrated. $15.50. Springfield, Ill.: Charles C Thomas, 1958.

Lesions of the Lower Bowel. By Raymond J. Jackman, M.D., M.S. 347 pages, illustrated. $15.50. Springfield, Ill.: Charles C Thomas, 1958.

Cyclopropane Anesthesia. By Benjamin Howard Robbins, M.D. 2nd ed. 293 pages, 74 illustrations. $9.00. Baltimore: The Williams & Wilkins Co., 1958.

Recent Advances in Cerebral Palsy. Edited by R. S. Illingworth, M.D., F.R.C.P., D.P.H. D.C.H. 413 pages, 136 illustrations, $12.00. Boston: Little Brown & Co., 1958.

Medulloblastoma. By Benjamin L. Crue, Jr., LCDR, M.C., U.S.N. 206 pages, 17 illustrations. $5.75. Springfield, Ill.: Charles C Thomas, 1958.

Reversicon; a Medical Word Finder. By J. E. Schmidt, Ph.B.S., M.D., Litt.D. 440 pages, $7.50. Springfield, Ill.: Charles C Thomas, 1958.

Leukemia. By William Dameshek, M.D., and Frederick Gunz, M.D., Ph.D. 420 pages, 142 illustrations. $15.75. New York and London: Grune & Stratton, 1958.

Cardiac Arrest and Resuscitation. By Hugh E. Stephenson, Jr., M.D. 378 pages, 31 illustrations. $12.00. St. Louis: C. V. Mosby Co., 1958.

Tumors of the Lungs and Mediastinum. By B. M. Fried, M.D., F.C.C.P. 467 pages, 340 illustrations and 4 color. $13.50. Philadelphia: Lea & Febiger, 1958.

Octavo congreso uruguayo de cirugia. December 10–12, 1957. 257 pages, illustrated. Sede: Parque Hotel, Rambla Presidente Wilson. Montevideo, Uruguay, 1957.

Transactions of the Western Section of the American Urological Association. Vol. 25. 199 pages, illustrated. El Mirador Hotel. Palm Springs, California, February 3, 4, 5, and 6, 1958.

Transactions of the Southeastern Section of the American Urological Association, Inc. 110 pages, illustrated. The Hollywood Beach Hotel. Hollywood, Florida, January 12, 13, 14, 15, and 16, 1958.

Physiology of Spinal Anesthesia. By Nicholas M. Greene, B.S., M.A., M.D. Foreword by John Gillies, C.V.O., M.C., F.R.C.P.E., F.R.C.S.E., F.F.A.R.C.S. 195 pages, 7 illustrations. $6.00. Baltimore: The Williams & Wilkins Co., 1958.

Die Intragluteale Injektion; eine Erlaeuterung der Anatomischen und klinischen Grundlagen. By Prof. Dr. Med. A. Von Hochstetter, Priv.-Doz. Dr. Med. H. K. Von Rechenberg, and Dr. Med. Rud. Schmidt. 27 pages, 19 illustrations. $1.15. Stuttgart: Georg Thieme Verlag, 1958.